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THE GERMINATION, GROWTH, AND FLOWERING
OF CYCLAMEN PERSICUM MILL

A THESIS

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of the requirements for the degree
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CHAPTER ONE

INTRODUCTORY REVIEW OF LITERATURE

ORIGINS

1.1 *Cyclamen persicum* Mill (syn. *C. indicum*, *C. vernale*) occurs naturally in the middle east from the Mediteranean to Iran (Good, 1964). This species usually occurs on hill slopes in thickett associations such as *Quercus thaburensis*/*Styrax officinalis* or *Salvietum trilobae*/*Alium subloruitum* (Zohary, 1962). Typical soils are dark rendzina types derived from middle Eocene rock with high levels of organic matter and little or no lime (Zohary, 1962). Occasionally *C. persicum* is found growing lithophytically directly into rocks of unusually high field capacity.

The limited information available and the divergence of modern hybrids from wild type makes it difficult to predict nutritional needs from the natural habitat of cyclamen. Natural habitats are seldom optimal and it is clear that differences in nutrition occur between cultivars of many species (Gerloff, 1973).

SEED GERMINATION

1.2 Seed Structure

Although *Cyclamen persicum* is a member of the dicotyledonae the embryo has only one cotyledon. The embryo is narrow and linear

the cotyledon being small and not expanded. The embryo cannot arise in the usual manner between the two cotyledons, rather it arises on the flank of the embryo at the transition zone between cotyledon and hypocotyl (Sundberg, 1977). The embryo is surrounded by a relatively large quantity of endosperm (Atwater, 1978). The thin fibrous seed coat includes an integument two cells thick with radical and inner walls of the inside layer cells thickened and lignified. The megasporangium wall shows reticulate thickenings (Woodcock, 1933; Martin, 1946).

1.3 Factors Affecting Germination

Consistent seed germination is altered by the following factors (adapted from Heydeker, 1969).

(i) Inherent vigour. Generally *C. persicum* is a difficult species to raise from seed and differences in germination vigour occur between varieties (Andersen, Widmer, 1975; Heydeker, Wainwright, 1976).

(ii) Physiological and cyclological defects due to premature harvest, deterioration in storage, or dormancy. After harvest cyclamen seed have an after-ripening requirement. During a period of 30 (Katsuki, Okazaki, 1968) to 90 days (Sumitomo, Kosugi, 1963) from harvest germination is slower and less even than for older seeds. This effect gradually reduces with time from harvest (Sumitomo, Kosugi, 1963). Krauze (1967) suspected the presence of a germination inhibitor in the seed coat which was removed by washing in running water. Anderson and Widmer (1975) also found that immersion of seed in flowing water for 15 hours improved germination speed and success. It has not been shown that the postulated germination inhibitor is a part of the after-ripening

phenomenon or that they are linked in any way.

Germination is inhibited by high (25 - 30 °C) temperatures (Massante, 1963; Heydeker, Wainwright, 1976) and in light (Sumitomo, Kosugi, 1963; Cathey, 1969; Massante, 1973). Optimum germination occurs in the temperature range 16 - 20 °C (Sumitomo, Kosugi, 1963; Schwemmer, 1977) and is probably most rapid near the top of this range (Menzel, 1972a). Recommendations for the pH of the medium vary from 5.2 - 7.0 (Sumitomo, Kosugi, 1963; Pockling, 1975; Lesaint, Brunet, 1976).

(iii) Pathological problems caused by seed, air, or soil borne microorganisms and storage fungi. It is difficult to distinguish the seed borne from environmental diseases. *Cyclamen persicum* cultivars are highly susceptible to disease at the seedling stage.

(iv) Mechanical damage as a result of faulty harvesting and handling.

(v) Storage. Generally cold and/or dry storage will greatly extend seed life. Cyclamen seed are relatively large containing ample stored food to last well. Massante (1963) found no difference in capacity to germinate between seed stored at 2 °C and at 10 °C for one to four years.

1.4 Germination Percentage

Cyclamen persicum percentage strike is more related to seed vigour and pathogenesis than to seed dormancy where storage and handling has been careful (Anderson, Widmer, 1975). Poor vigour

may be manifested by greater sensitivity to environmental conditions under which a seed will germinate. Reduced speed and uniformity of germination, or slow abnormal growth may occur before any decline in germination percentage (Heydeker, 1969).

Cyclamen persicum seed is normally of slow uneven germination, and highly sensitive to environmental factors when compared with other species so the buffering effect on percent germination of reduction in seedling quality is less important. An ideal environment enabling consistent high levels of germination of cyclamen is unknown (Anderson and Widmer, 1975). Unusual care must be taken to exclude potential disease organisms. Pre-sowing treatments have been carried out to this end using calcium or sodium hypochlorite solutions (Neuray, 1971d; Anderson and Widmer, 1975) or hot (50 - 60 °C) water (Anderson and Widmer, 1975). Fungicides including captan, truban, thiram, benomyl, phenyl mercury acetate, zineb, and thiabendazole have usually given no significant advantage and were occasionally detrimental to cyclamen germination (Anderson and Widmer, 1975; Grundler, 1974; Heydeker and Wainwright, 1976).

Considerable variation can occur between and within cultivars of cyclamen (Loesser, 1971; Anderson, Widmer, 1975; Neuray, 1971d). Menzel (1972c) found that percentage germination is often slower with small compared with large seed. As there are strong cultivar differences in seed size (Heike, 1971), size may partly account for poor germination with certain cultivars.

Improvements in germination may be made by breeding (Sparnaaij and Tichelaar, 1975; Pockling, 1975) and by improving conditions

during seed production (Pockling, 1975).

1.5 Speed and Uniformity

Ideally seeds should not only germinate immediately on sowing, but simultaneously. *Cyclamen persicum* seed germinate slowly and unevenly, often there is a long period between the germination of the first and last seeds (Heydeker, Wainwright, 1976). These problems are explained at least in part by the structure of the seed described previously. Before germination can occur the embryo must grow within the seed to complete the absorption of the endosperm. This explains the slowness of germination by comparison with, for example, the compositae which have independent embryos capable of immediate growth after imbibition (Atwater, 1978). The variation in *Cyclamen* seed size alone is enough to explain much of the variability in time to completion of this process. Efforts have been made to overcome these problems: (a) by enabling the absorption of endosperm and other pre-emergence processes to occur before sowing, and, (b) by accelerating processes occurring before emergence.

The most simple and obvious technique is water imbibition in still or flowing water for up to 75 hours. Although seed are completely imbibed within 12 hours, 75 hours of running water improves germination even further (Anderson and Widmer, 1975). The advantage would appear to be conferred by a process more complex than imbibition alone. Flowing water being more effective than still water gives some (small) degree of support to the inhibitor leaching theory. For this type of seed Atwater (1978) recommended imbibition of relatively low (5 - 15 °C) temperatures to curtail the use of oxygen in respiration making it more

available for other uses such as neutralisation of inhibitors and generation of hormones.

The most sophisticated techniques of this type allow imbibition to occur to levels which allow pre-emergence processes to occur while emergence of the radicle is prevented by one of several means (Heydeker, Higgins, and Gulliver, 1973; Heydeker, Higgins, and Turner, 1975). On sowing, the seed are immediately ready for emergence. Two means of preventing emergence during several weeks of treatment have been adapted for cyclamen by Heydeker and Wainwright (1976). An osmoticum of -8 to -11 bars polyethylene glycol (PEG) allows sufficient imbibition for pre-emergence processes, but not for emergence. Emergence can also be prevented at high temperatures (see above). Both these techniques allowed improvements in speed and uniformity of germination, PEG treatment being the better of the alternatives. Jeff (1976) on repeating the PEG treatments gained variable results. She was not convinced that this treatment was as worth while for general use as accurate temperature control after sowing. Difficulties prevent large scale application of the PEG techniques (Heydeker, Wainwright, 1976).

Results from attempts to accelerate processes occurring after sowing have been equally inconclusive. As has been mentioned germination of seed at least 90 days old is faster than for fresh seed. Red, and far red light treatments, thiourea and potassium nitrate are all ineffective in accelerating germination. Gibberellic acid treatments did accelerate germination while causing an expelled embryo problem which reduced survival (Anderson and Widmer, 1975). This treatment, it was concluded, was not overcoming a dormancy condition

but was producing typical gibberellin cell division and elongation effects. Environmental influences also affect the speed of germination. Pockling (1975) found that germination is fastest at pH 5.0 - 6.0

NUTRITION OF CYCLAMEN PERSICUM

1.6 Comparative Nutrition

The mineral nutrient requirements of plants are strongly influenced by Genotype (Gerloff, 1963). Qualitative differences may occur between the types of nutrient required or the form in which a nutrient is best utilised. Quantitative differences occur between the total amounts, relative proportions, and ranges of nutrient levels tolerated.

The nutrients investigated, nitrogen (N), phosphorus (P), potassium (K), and calcium in the form of lime (L) are essential to all higher plants. The major qualitative preference occurs between different N sources - nitrate (NO_3^-) and ammonium (NH_4^+).

Quantitative differences between the requirements for these major nutrients occur between species, varieties and stage of plant development (Gerloff, 1963; Penningsfield, 1972; Bould, 1972; Thomas, 1974).

1.7 Responses

The classical method of biological investigation varied a single factor while others were held constant (Heath, 1969). The objective was to find the minimum below which growth would not proceed,

the optimum at which growth was greatest and the maximum beyond which growth was again depressed. Justification for this type of experiment was the law first postulated by von Liebig (cited Heath, 1969) for nutritional factors and extended by Blackman (1905) to cover all factors. Blackman stated "when a process is conditioned to its rapidity by a number of factors the rate of the process is governed by the pace of the slowest factor". Responses were expected to be linear until the measured factor was no longer limiting beyond which no further response would occur. That both additive and interactive responses to more than one factor can occur was first shown by Harder (1921, as cited by Heath). Interactive relationships have been shown between nutrients and between nutrients and other factors (e.g. Bates, 1971; Bould, 1972).

No information is available concerning interactions occurring in the nutrition of *Cyclamen persicum*. Interactions have been shown for other pot-plants including *Adiantum radiannum* (Khoo, 1979), *Ficus elastica* (Thomas, 1979), and *Coleus blumei* (Lai, Thomas, and Love, unpubl.).

1.8 Optimisation

Ideally nutrients must be provided at sufficient balanced levels to grow the highest quality plant in the shortest possible time. It is easy enough to determine levels of nutrition which cause visible deficiency or toxicity symptoms. *Cyclamen persicum* tolerates a wider range of nutrient levels than most plants without obvious physiological disease (Widmer *et al.*, 1979). This makes the determination of optimal nutrient levels and the relationships between

nutrients more difficult.

1.9 The Nutrients

The need for nitrogen shows up in almost all plant growth responses. Pot-plant species are no exception and generally show strong nitrogen responses for most parameters measured (e.g. Thomas, 1979; Khoo, 1979; Teoh, 1979). Quantitative differences in requirement are common between species but are much reduced when relative growth and assimilation rates are taken into account. A fast growing species such as *Chrysanthemum morifolium* may assimilate twice as much N in a month as does *Cyclamen persicum* over a year (Bunt, 1976) but the amounts of nitrogen used per unit of growth will be much closer to each other.

Thomas and Spurway (1975a) concluded that $60 - 70 \text{ g N m}^{-3} \text{ month}^{-1}$ in the form of slow release fertilisers was sufficient for most slow growing container plants and that $120 \text{ g N m}^{-3} \text{ month}^{-1}$ were required by the more vigorous plants. Bunt (1976) recommended that usually $200 - 250 \text{ g N m}^{-3}$ was a safe level to add to the potting medium at any one time (excluding potential from slow release).

In general the ability to respond to nitrogen is strongly related to light levels (Bunt, 1973; Mengel, Kirkby, 1978). Miura (1968, 1970) found that high N levels increased leaf but suppressed root growth of *Cyclamen persicum*.

Qualitative differences occur between plant species' responses to Ammonium and Nitrate N sources. Plant pathogenesis (Huber, 1974) and the soil environment, especially pH, are also influenced by N

source (Springer, 1968; Haynes, Goh, 1976).

Springer found no significant differences in growth of *Cyclamen persicum* with different N sources. Sources of nitrogen are important in relation to diseases of cyclamen. *Thielaviopsis basicola* is suppressed by ammonium (Smiley, 1975) whereas *Fusarium oxysporum* disease is reduced in severity in the presence of nitrate (Huber, 1974). *T. basicola* causes root rot of cyclamen *F. oxysporum* f. sp. *cyclaminis* is a vascular wilt (see appendix 2).

Although P uptake is usually low relative to that of N and K, P influences the utilisation of many other nutrients and is critical for the utilisation of applied N (Gilbert, 1957). Interactions between N and P have been shown for a number of plants studied (e.g. Thomas, 1979; Khoo, 1979). Phosphorus is readily mobilised within the plant, its shortage reduces growth and delays maturation.

Flowering of cyclamen may be delayed by P shortage (Gugenhahn, 1969b) and mixed fertilisers containing high P and K may result in an increased number of flowers (Schwemmer, 1975) of higher quality (Miura, 1970). On the basis of his results Schwemmer postulated an interaction between P and K, Miura (1968) found that P did not affect shoot or root growth but found (Miura, 1970) that fresh weight was highly correlated with foliar P levels.

Most plants have a high requirement for K with a wide luxury range beyond (Bunt, 1976) in which the balance with other nutrients becomes more important than concentration (Boodley, 1969). There is a strong relationship between K and nitrate uptake and assimilation

(whereas K may compete with ammonium uptake) which leads to the appearance of strong interactions between N and K (e.g. Khoo, 1979; Thomas, 1979). High K levels may counteract sodium toxicity but may contribute to Mg and Ca deficiencies (Boodley, 1969; Klougart, Bagge Olsen, 1969).

Haber (1975) found that K had little influence on uptake of trace elements by cyclamen except at very high K levels where uptake of Mn, Fe, and Zn was depressed.

Freisdorf and Verschenstalt (1973) found no response of cyclamen vegetative growth to K whereas Miura (1968, 1970) had found that K increased leaf size and fresh weight and was necessary for root growth. Freisdorf and Verschenstalt (1973) found no influence of K on flower stalk length and strength or flower colour, yet Augé and Vidalie (1977) report that high K levels favour production of higher quality flowers. Freisdorf and Verschenstalt did report an increased number of flowers produced in response to K. These slight differences in result could be a result of the P, K interaction postulated by Schwemmer (1975). All seem agreed (including also Mantrova *et al.* 1970) that high K levels are necessary for the least some aspects of cyclamen growth.

Lime supplies calcium and influences the availability of other nutrients through its effect on pH, Haber (1975) found that liming enhanced foliar levels of calcium molybdenum and copper content in cyclamen dry matter. Boron iron and manganese uptake were depressed and zinc content remained unchanged. This result is in accordance with generalised lime influences on trace element availability for most

plant species (e.g. Hannan, Holley, Goldsbery, 1978).

The pH of the medium is influenced by other factors in the soil environment including magnesium (Mg), N source, temperature, and gross structure (Cochrane, 1958).

Hangitae (1976) reported that although cyclamen prefer low pH conditions, they have a high requirement for calcium (Ca). Excessive Ca caused a leathery appearance of leaves, suppression of growth and Ca uptake was not highly correlated with fresh weight (Miura, 1968, 1970). A qualitative change occurs with stage of growth. Lesaint and Brunet (1976) reported that during germination and early growth in peat, the optimum for cyclamen was pH 6 but by the second month this optimum had dropped to pH 5.5.

The influence of pH on soil microflora includes the pathogen of cyclamen *Thielaviopsis basicola*, pathogenesis by which several species has been depressed by lowering pH. Very low pH may be needed in the presence of high P or where calcium combine with low pH (Chapman, 1965; Lucas, 1965; Smiley, 1975).

1.10 Nutritional Research on Nursery Plants

A generalised knowledge of plant nutrient needs has led to attempts to create a single ideal potting medium in which all plants can be grown (e.g. John Innes compost: Richards; Warneke; Marsh, Aljibury, 1964, University of California mixes: Baker, 1957; Cornell peat-like mixes: Cornell recommendations, 1974). Use of a single mix often prepared in bulk for use by several nurseries enables economy of scale and division of labour to more productive areas.

Although a single mix with minor modification can be used to grow a wide range of plants recent work clearly indicates that standardised media do not produce optimum or even good rates of growth for many plants (Thomas, 1979). Despite constant growing conditions macro and micronutrient requirements differ for each species (e.g. Penningsfield, 1972; Dirr, 1974).

Rapidly growing species such as *Chrysanthemum morifolium* or *Coleus blumei* may require high levels of nutrients (Bunt, 1976) which are toxic for other species like *Fatsia japonica* (Thomas, 1979) which was found to be tolerant of low levels of macronutrients. Some species may show unusual sensitivity to a particular nutrient. *Ficus elastica*, while highly responsive to fertilisers generally, is unusually responsive to P (Seager, 1973; Thomas, 1979). *Anthurium andraeanum* requires particularly high K levels (Bik, 1976). Several members of the proteaceae have been found to be highly sensitive to P toxicity at levels to which most plants show a positive response (Thomas, 1979).

This similarity between nutritional preferences of different members of a family does not appear to have been repeated in the Primulaceae. *Primula obconica* for example, one of the few other species of primulaeaceae also grown as a pot-plant has been shown to have quite different responses to fertilisation from those of *Cyclamen persicum* (Gugenhahn, 1969a). Penningsfield (1972) reported that *P. obconica* is tolerant of a relatively narrow deviation in macronutrient supply. This contrasts with the wide range of nutrient levels tolerated by cyclamen.

FLOWERING

1.11 Flower Development

Cyclamen persicum flower development begins on the flank of the radially symmetric shoot apex near the axil of the sixth leaf to form (Sundberg, 1977). Before flower initiation occurs extensive proliferation of tissue at the base of the first leaves has displaced the originally lateral apex to the centre of the developing shoot system (Sundberg, 1977). The sixth and seventh leaves grow much more rapidly than the others. This may be associated with the beginning of flower initiation (Sundberg, 1977).

Flower primordia continue forming in leaf axils adventitiously and terminally as long as the plant continues growth (Neuray, 1977). The floral growth rate is constant from flower to flower and independent of the growth rates of respective subtending leaves (Sundberg, 1977).

1.12 Light

Hageman (1959) stated that *Cyclamen persicum* was a short day plant but most others have agreed with Post (1949) who found this species indifferent to photoperiodism. The evidence is not conclusive - the long time lag between flower initiation and flowering makes photoperiodic study difficult. Neuray (1973) confirmed that light does influence flowering of cyclamen. Evidence was found to support the following statements.

- (i) The longer the day the greater the number of buds produced.
- (ii) Light intensity as well as daylength is important.
- (iii) Vegetative growth was not noticeably influenced by the treatments. In these trials some cultivars were found to be light

indifferent. Widmer *et al.* (1976b) also found that supplementary lighting advanced flowering, but that the early peak of bloom brought about by continuous light also meant a shorter flowering period. In contrast with these results, Hakozaki and Takenaga (1972) found that flowering was earliest under heavy shade.

These reports do not link any environmental factor with flower initiation rather with growth after initiation. A study of initiation would need to use plants before the six leaf stage.

1.13 Soil Temperature

It has been recommended more than once that raising soil temperature to between 20 and 24 °C for up to six weeks will accelerate development of *C. persicum* flowers (Anderson, 1966, Maatsch, 1971). Unfortunately, recommendations differed on when this treatment should be applied. Stephens and Widmer (1976) carried out a detailed experiment intended to clarify what temperature was best at each stage of plant growth. Response to soil temperature did change with stage of vegetative development, but it was low temperatures which were most effective in advancing flowering.

If the soil was held at 13 °C for four weeks beginning when plants are on the verge of flower initiation (i.e. the five leaf stage) flowering was up to 70 days earlier than plants treated at higher temperatures or at different stages. There is no response prior to flower initiation therefore the effect is one of accelerating flower development rather than initiation.

It is not known which part of the plant in or near the soil

surface is receptive to this low temperature treatment. Vegetative growth was only temporarily delayed by reduced soil temperature. This finding may justify the practise of some European growers who plunge their cyclamen in the cool ground over the summer months (Widmer, 1976).

1.4 Air Temperature

Maatsch and Kaefer (1957) found that *C. persicum* grown at 17 °C flowered 25 - 30 days faster than those grown at 13 °C. Asma (1973) found that at 20 °C a strong negative influence on the development of foliage, bud formation and flowering becomes apparent. Maatsch and Kaefer, and Menzel (1972b) recommended that a four week period at 20 - 22 °C in the early stages of growth will advance flowering. This conflicting picture is compounded by the observation by Vickerman (1973) that flower colour was more intense, and flower stalks stronger and straighter on plants grown at 6 °C rather than higher temperatures.

It is probable that different temperature optima occur at various stages of growth perhaps a higher temperature being of advantage to flower initiation than to later development. Optimal temperatures have been found to differ for different *C. persicum* cultivars (Kristofferson, Bergerund, 1972; Mollnar, Williams, 1977).

Although the optimal environmental conditions for flower initiation and development of *Cyclamen persicum* have not been clearly defined control of soil and air temperature, nutrition, lighting and supplementary carbon dioxide (Widmer *et al.* 1979) can substantially reduce time to flowering (Mollnar, Williams, 1977).

1.5 Chemical Treatments

For more than 20 years attempts have been made to chemically advance flowering of cyclamen. Hoard (1958) reported that gibberellins (GA) were without effect on *C. persicum*. Hoard however, was the exception, Kohl and Kofronek (1957), Jansen (1960), Neuray (1971a,b,c,) Jeff (1977), and Parups (1979), have reported that more rapid development of flowers occurs as a result of GA spray applications. Neuray (1971a), in the most detailed examination of this response so far, confirmed that it is not flower initiation but subsequent development which is influenced by GA treatments. Normal peduncle growth begins very rapidly, slowing slightly at an intermediate stage, and finishing with a burst of rapid growth. As a result of GA treatment peduncle growth was faster than untreated peduncles at all stages. Peduncles produced were thinner and longer. In the absence of any histological evidence, Neuray assumed that the response was simply an increase in cell elongation and transverse cell division, a common response to gibberellins. At excessive levels of GA peduncles may become too tall and weak to be self-supporting, the flowers may be incompletely reflexed or distorted.

Jansen (1960) reported that the effectiveness of GA treatments depended upon the number of applications, the concentration of GA, and in particular the stage of bud development at which treatment was applied. The resulting recommendation was for two or three 10 ppm GA₃ sprays to the crown at 24 hour intervals when the peduncles were 1 - 2 cm long. Flowering began earlier, and a greater number of flowers were open at once than for other treatments. A single dose of 30 ppm GA₃ resulted in excessive elongation of peduncles. Jeff (1977)

recorded this effect when only 25 ppm GA was applied to the plant while Widmer *et al.* (1974) found no adverse effects caused by 50 ppm applications. Parups (1979) actually observed a shortening of flower stalks at 25 ppm GA.

All authors have specified the concentration of GA used, but some did not specify either the volume of solution or the total amount of GA applied to the plant (e.g. Jeff, 1977; Seeley, Kumpf, 1976a,b; Neuray, 1977b). A conversion, where possible, to a common unit shows that applied quantities varied between 75 and 1000 μg per plant. This calculation does not account for differences in technique such as spraying the crown rather than the whole plant (Anon, 1974, Widmer, 1976; Augé, Vidalie, 1977) and differences in loss due to runoff.

Applications of 400 μg plant⁻¹ have in some cases caused distortion of floral parts (Parups, 1979), yet routine use of this quantity seems to have caused no problem for others (Widmer *et al.* 1974; Widmer, 1976). Augé and Vidalie (1977) have reported improvements in time of flowering with as little as 75 μg GA plant⁻¹ but Parups (1979) observed only small differences with 200 μg plant⁻¹.

The stage of plant growth at which to spray with GA has not been standardised. Several types of recommendation exist with variation within and between each. Spraying at a given length of peduncle recommendations vary between 0.05 cm to 5 cm (Jansen, 1960; Gorini, 1963; Jeff, 1977; Parups, 1979).

Neuray (1971a) recommended spraying when four or five peduncles

were visible. Widmer (1976) sprayed when plants were 20 - 25 cm in diameter and at other times 60 - 100 days before required flowering was specified (Widmer *et al.* 1974, also Anon, 1974; Seeley, Kumpf, 1976a,b; Augé, Vidalie, 1977). Time from sowing ranged from five months to eight and a half months (Widmer *et al.* 1974; Augé, Vidalie, 1977; Jeff, 1977, Widmer *et al.* 1979). It is noteworthy that Kohl and Korronek (1957) found that the adverse effects of excessive GA differed according to the stage at which the plant was treated.

Variability in response to GA treatments occurs between cultivars of *C. persicum* (Neuray, 1971a, Augé, Vidalie, 1977; Jeff, 1977; Seeley, Kumpf, 1976). Parups (1979) found that whereas GA treatment improved the flowering date of the latest cultivar by three weeks the earliest cultivar gained only a few days. All treated cultivars flowered together. In view of the probability that the early cultivars were treated at a later stage in their development it cannot be generalised that early flowering cultivars are less responsive to GA treatments than later flowering types. Widmer (1976) recommended 200 µg gibberellic acid (GA₃) per tetraploid plant but only 120 µg GA₃ plant⁻¹ for fast flowering diploid F-1 hybrid varieties.

Differences in responses of cyclamen to different gibberellins have been demonstrated (Neuray, 1971a). Most authors used GA₃ but some have failed to specify the gibberellin used.

The influence of GA treatment is not necessarily large and although flowering has been advanced by more than 35 days (Widmer, 1976) the advancement in flowering has more commonly been reported as under

three weeks (e.g. Parups, 1979; Jeff, 1977; Augé, Vidalie, 1977) and may be only a few days. Once begun however, flowering of treated plants progresses much more rapidly than untreated ones. More flowers appear simultaneously on treated plants but the length of the flowering period may be drastically reduced (Augé, Vidalie, 1977), Widmer *et al.* 1974, Neuray, 1971a) when compared with untreated plants.

Some attempts have been made to avoid or overcome the adverse side effects of GA_3 treatment. Successive treatments at small doses were thought to cause fewer problems than large single applications (Jansen, 1960; Augé, Vidalie, 1977). Neuray (1971a) and Widmer (1976) found no advantage in applying more than one treatment.

Sachs *et al.* (1960) have shown that AMO, CCC, and Phosphon D inhibit transverse more than horizontal cell division. When CCC, B-nine, or IBA were used by Neuray (1971a) in combination with GA_3 , they failed to prevent adverse effects without losing the advancement of flowering of *Cyclamen persicum*. The two retardants, CCC and B-nine, unexpectedly had a positive influence on the first stage of peduncle growth in the absence of GA.

An alternative chemical AC94377, caused less flower distortion at $400 \mu \text{ plant}^{-1}$ than did GA_3 (Parups, 1979). Atrinal (dikegulac) also enhances cyclamen flower development (Bocion *et al.* 1978) as well as causing more robust vegetative growth (Bocion *et al.* 1977). Pyradon has also been tried (Rolli, 1972).

Little is known about the physiology controlling cyclamen flower initiation. Some control over the subsequent development of

the flowers can be exercised by adjustment of environmental factors and by chemical treatments. Although GA treatments may improve uniformity of flowering, 5 - 10% of plants may flower more than 35 days later than the majority of plants (Widmer *et al.* 1974).

OBJECTIVES

1.16 Expensive cyclamen seed are not germinated at optimum levels on a routine basis. The aim was to investigate several simple seed pretreatments intended to improve percentage, speed, and uniformity of germination.

The objective of the nutritional trials was twofold. It was intended to carry out experiments to determine the influence of N, P, K fertilisation and Liming and obtain response surfaces for the interactions between any pair of nutrients on growth of *Cyclamen persicum* in conditions similar to common New Zealand nursery practise. In conjunction with this it was hoped to extend by using trials of appropriate design, the standardised comparative nutrition information already produced for several other species by Thomas (1979), Khoo (1979), Teoh (1979).

The growth regulator trials were intended to determine the value of gibberellin advancement of flowering for New Zealand conditions including the influence of time of treatment and interactions between gibberellic acid and various growth retardants with a particular view to controlling the bad side effects sometimes occurring as a result of GA treatment.

CHAPTER TWO

THE INFLUENCE OF SEVERAL PRE-SOWING TREATMENTS ON GERMINATION OF CYCLAMEN PERSICUM MILL

2.1 Abstract

Several pre-germination treatments were carried out with the objective of improving germination percentage, speed, and uniformity. Soaking seed in water, and in Gibberellic acid improved germination speed, but the latter reduced survival. Terrazole, Benomyl, Thiram, and Sodium hypochlorite treatments did not reduce or delay germination as has been reported elsewhere, but conveyed no consistent advantage.

2.2 Introduction

Improvements in germination of *C. persicum* have been achieved through sodium and calcium hypochlorite surface disinfection treatments (Neuray, 1971b; Anderson and Widmer, 1975) but optimum germination has not been attained on a routine basis (Widmer, 1976). *C. persicum* seed show variability in uniformity, speed, and percentage of germination and are highly sensitive to environmental and pathogenic factors.

In 1977 2.75 - 4.13 cents (NZ) was paid per cyclamen seed. Low and irregular germination of this expensive seed will contribute to already high production costs particularly with increasing use of highly priced F_1 hybrid seed.

Germination of freshly harvested cyclamen seed tends to be slow and irregular (Sumitomo, Kosugi, 1963; Katsuki, Okazaki, 1968). Therefore the following series of experiments uses aged seeds. The ideal assessment of germination is taken when a viable self-supporting photosynthesising plant has been produced (Heydeker, 1967). To avoid discrepancies between results, seedlings must be grown sufficiently large that defects can be seen and borderline cases included (or excluded) consistently.

MATERIAL AND METHODS

2.3 Experiment 2A

The effect of pre-sowing water imbibition treatments on germination of *Cyclamen persicum* Mill.

Cyclamen seed of varieties 'Plain rose of Aalsmeer', 'Early deep Scarlet', 'Fringed Mont Blanc', 'Plain white Mont Blanc', and 'Perle of Zehlendorf' (obtained from Arthur Yates and Company) were surface disinfected in 5% sodium hypochlorite solution for one minute. The seeds were rinsed and soaked in sterile distilled water for 0, 1, 12, or 48 hours. Forty seeds from each variety were subject to each treatment being blocked according to variety, i.e. five randomised blocks.

On 31st March, 1977, seed were sown into trays of Springhill sphagnum peat containing 75 g m^{-3} terrazole. The trays were placed in a germination cabinet in the dark at 15°C , and watered as required. After one month the trays were removed to a glasshouse

and the emerging seedlings watered fortnightly with lush fertiliser. A drench of benomyl was applied at this stage.

2.4 Experiment 2B

The influence of a range of treatments on the germination of *C. persicum*.

Seeds in this and subsequent experiments had been stored for 18 months to eliminate the post-harvest germination delay. Massante (1963) has shown that cyclamen seed can be stored for long periods without loss in the capacity to germinate. Seed of varieties 'Aalsmeer giants' and 'Foremost mixture' (Colegraves' Seeds, England) were pretreated or sown with a treatment solution or suspension as specified in Table 2.2. Seeds were sown on 3rd November, 1978, in sterile petrie plates on germination paper which had been soaked in 10 ml of sterile distilled water or a treatment solution/suspension. The plates were placed in the dark at a mean temperature of 19.4 °C with a maximum of 23 °C and a minimum of 12 °C. Distilled water was added in 5 ml aliquots as required.

2.5 Experiment 2C and 2D

The effect of Gibberellic acid, thiram, benomyl, Terrazole and hot water treatments on germination of *C. persicum*.

Two experiments were intended to further investigate the preliminary results from Experiment 2B. Cyclamen varieties: 'Early pink', 'Plain perle von Zehlendorf', 'Plain white (Mont Blanc)', 'Plain rose von Aalsmeer', 'Early pure white', 'Early flowering deep scarlet'

(Arthur Yates, NZ), were surface disinfected in sodium hypochlorite (see expt. 2A) and after treatment as detailed in Tables 2.3 and 2.4, were germinated in conditions described for Experiment 2B. The experiment was therefore a randomised block experiment of six replicates.

2.6 Assessment and Analysis

In Experiment 3A germination was recorded as when seedlings emerged from the soil. In Experiments 2B, C, and D, emergence from the seed was recorded but germination was not regarded as complete and successful until a clearly defined corm and root system had formed and the first leaf was extending. The variation in morphological development creates a major source of error in the timing of this stage. Uniformity of germination was measured as the days between germination of the first and last seeds. Duncan's new multiple range test was used to compare all treatments with each other.

Fungal colonies from the seed plates were grown on potato dextrose agar and examined for pathogens.

Table 2.1. Experiment 2A: The Effect of Pre-Sowing Water Imbibition Treatments on Germination of *C. persicum*.

Treatment	Mean % Germination		Mean Days to Emergence	
Control	25	a	51	a
1 hour imbibition	23	a	49	b
12 hours imbibition	26	a	44	c
48 hours imbibition	29	a	39	d
CV %	15.6		4.33	

Any means not followed by the same letter were significantly different at the 5% level according to Duncan's new multiple range test.

RESULTS

2.7 Experiment 2A

Overall germination was poor and treatments showed no significant influence on percentage germination (Table 2.1). Speed of germination was improved according to the length of imbibition treatment. A 48 hour water soak reduced mean germination by 12 days.

Table 2.2. Experiment 2B: The Influence of a Range of
Treatments on Germination of *C. persicum*

Treatment	% Germination		Days to Germinate		Uniformity	
	Mean		Mean		Mean	
Untreated	52	abcde	40.3	b	38.5	abc
Water soak 1 min	55	abcde	41.0	bc	46.0	bc
SD (control)	41	abcd	47.0	de	44.6	abc
SD 2 hr water soak	48	abcde	40.4	bc	27.5	abc
SD GA ₃ 1 ppm*	30	a	40.4	b	12.0	a
SD 2 hr soak 1 ppm GA ₃	40	abcd	46.9	de	33.0	abc
SD 2 hr soak 10 ppm GA ₃	43	abcde	40.8	b	22.0	abc
SD 2 hr soak 50 ppm GA ₃	31	ab	39.9	b	47.5	bc
SD 2 hr soak 100 ppm GA ₃	32	abc	34.6	a	35.0	abc
Hot (60° C) water 5 min soak	32	abc	41.6	bc	47.5	bc
.01% a.i. benomyl pretreatment	52	abcde	43.8	bcde	33.5	abc
SD .01% a.i. benomyl pretreatmt	58	de	43.4	bcde	38.0	abc
1.0% a.i. benomyl pretreatmt	60	de	43.1	bcd	36.0	abc
SD 10 ppm Terrazole*	61	de	41.4	bc	30.8	abc
10 ppm Terrazole*	44	abcde	40.4	b	17.0	ab
100 ppm Terrazole*	57	cde	45.4	bcde	46.9	bc
1000 ppm Terrazole *	56	bcde	48.0	e	41.0	abc
Benomyl and Terrazole*	60	de	40.6	b	40.5	abc
0.1% a.i. Thiram pretreatment	59	de	41.6	bc	51.0	c
SD 0.1% a.i. Thiram pretreatmt	67	e	43.8	bcde	47.5	bc
0.5% a.i. Thiram pretreatment	59	de	46.3	cde	35.5	abc
1.0% a.i. Thiram pretreatment	58	de	44.3	bcde	35.0	abc
CV %	24.5		5.38		38.6	

* Supplied as suspension or solution in the water in which the germination pad was soaked

** 0.1% Benlate pretreatment and 10 ppm Terrazole*

SD = surface disinfected for one minute in 5% Sodium hypochlorite solution

Pretreatment = dip for one minute.

2.8 Experiment 2B

Although a high degree of significance was not achieved in this preliminary trial the results (Table 2.2) suggested the following:

(i) That although a faster rate of germination occurred as a result of higher levels of GA_3 treatments, these treatments tended to reduce germination percentage while showing inconsistent influence on uniformity.

(ii) The fungicidal treatments improved germination percentage but here Terrazole and Thiram showed a slight tendency to slow germination.

(iii) Hot water reduced germination percentage.

Table 2.3. Experiment 2C: The Effect of Gibberellic Acid on Germination of *C. persicum*

Treatment	% Germination		Days to Germinate		Uniformity	
	Mean		Mean		Mean	
SD (surface disinfected control)	64.8	b	39.9	a	32.3	a
SD 0.1 ppm GA ₃ *	76.7	a	39.1	a	27.3	a
SD 1.0 ppm GA ₃ *	56.7	bc	39.0	a	25.7	a
SD 10 ppm GA ₃ *	41.8	d	35.9	ab	28.2	a
SD 1 ppm GA ₃ pretreatment	56.5	bc	33.7	b	13.2	a
SD 10 ppm GA ₃ pretreatment	45.3	d	33.9	b	18.5	a
SD 50 ppm GA ₃ pretreatment	48.8	cd	27.9	c	36.3	a
SD 100 ppm GA ₃ pretreatment	49.0	cd	32.2	b	21.5	a
CV%	15.4		10.2		61.7	

* Supplied with the solution in which the germination pad was soaked (10 ml).

Pretreatment here means a two hour soak.

Treatments not followed by a common letter were significantly different according to Duncan's test at 5%.

2.9 Experiment 2C

Gibberellic acid treatments gave up to eight days improvement in germination time (Table 2.3) but the levels which gave these improvements resulted in 15% reduction in germination strike (Table 2.3).

Pre-soak GA_3 treatments showed greater improvements in germination speed than where the solution was included in the germination solution. No significant changes in uniformity of germination occurred.

2.10 Experiment 2D

Overall no significant differences occurred between treatments in percentage germination however because the controls of two varieties showed an average 92.5% germination in the control they were excluded from a repeat analysis of variance which showed a significant germination improvement as a result of 10 ppm Terrazole treatment and 0.1% a.i. benomyl pretreatment (Table 2.4).

A 1.0% a.i. benomyl pretreatment significantly improved speed of germination. No differences in uniformity were significant.

It was not possible to determine causes of failure. Fungi identified growing on seeds, and those isolated were all common saprophytes. This does not prove that pathogens had not been or were not still present.

Table 2.4. Experiment 2D: Effects of Various Fungal Protection Treatments on Germination of *C. persicum*

	% Germination		% Germination*		Days to Germinate		Uniformity (days)	
	Mean		Mean		Mean		Mean	
SD Hot (60 °C) Water 5 min soak	56.2	a	24	a	43.7	a	26.5	a
SD (surface disinfected control)	57.3	a	40.7	b	40.5	ab	32.3	a
SD 0.1% a.i. Thiram pretreatment	68.0	a	44.3	bd	43.1	a	39.5	a
SD 1.0% a.i. Thiram pretreatment	66.7	a	48.7	bde	41.9	a	20.4	a
SD 10 ppm Terrazole**	79.0	a	63.3	e	40.2	ab	20.2	a
SD 1000 ppm Terrazole**	70.8	a	41.7	b	37.0	b	27.3	a
SD 0.1% a.i. benomyl pretreatment	75.3	a	57.3	de	37.9	b	15.8	a
SD 1.0% a.i. benomyl pretreatment	71.3	a	45.7	bd	31.0	c	18.2	a
CV %	15.4		24.7		7.57		54.6	

* Varieties: Plain white, early flowering deep scarlet and plain rose Vaalsmeer only. Those means not followed by a common letter were significantly different according to Duncan's new multiple range test at the 5% level.

** Supplied in the solution in which the germination pod was soaked. Pretreatment here means a 1 minute dip.

2.11 Discussion

Imbibition treatments improved speed of germination without improving germination strike (Table 2.1). Anderson and Widmer (1975) found that imbibition was complete within 12 hours but that, as has been found here also, germination improved further on soaking for longer than 12 hours. Anderson and Widmer (1975), Hakozaiki (1973) found improvements in germination percentage as well as speed as a result of water soak treatments but their method of data collection at fixed dates could have resulted in misinterpretation of late germination as a failure.

Because seed populations vary continuously it is possible to draw conclusions about the successful population from the size of the unsuccessful one (Heydeker, 1969). The high proportion of failures tends to indicate that present successes were near failures. What we cannot do is draw conclusions about the imbibition response of the failed population from that of the survivors. This could mean that in conditions favouring high levels of germination the response to water soak treatments could differ from that found here.

Poor germination levels in Experiment 2A can be attributed to erratic temperature control by the germination cabinet. Germination of *C. persicum* is inhibited at temperatures over 20 °C (Massante, 1963; Heydeker, Wainwright, 1976).

Although gibberellin treatments improved speed of germination in both Experiments 2B and 2C (Tables 2.2, 2.3), strike was reduced. Similar results have been reported by Anderson and Widmer (1975). This treatment does not influence a known dormancy condition, the delay

in germination of recently harvested seed reported by Sumitomo and Kosugi (1963) and Katsuki and Okazaki (1968) should not have influenced germination of these aged seed. It is therefore concluded that the effect was a result of typical gibberellin cell division and elongation effects (Wareing, Philips, 1970). Anderson and Widmer (1975) reported that the increased losses as a result of GA treatment were due to premature expulsion of the embryo from the seed coat. This phenomenon was not observed in these experiments.

Gibberellin treatment is not justified when the slight gain in germination speed is balanced with the expense of chemicals and more importantly, the loss of very expensive seed. This conclusion was also reached by Anderson and Widmer (1975).

Fungicidal treatments occasionally produced significant improvements in germination (Tables 2.2, 2.4) and in no case did such treatments reduce germination percentage. This contrasts with other work where fungicides were observed to depress germination of *C. persicum*. Anderson and Widmer (1975) found thiram, truban, captan and benomyl all tended to inhibit germination. Valaskova (1974) found that cyclamen germination was sensitive to a wide range of soil disinfection treatments and Grundler (1974) also found poor emergence following thiram treatment but improvements with phenyl mercury acetate. Kosteljik (1970) reported improved germination as a result of benomyl treatment but Heydeker (1976) found no significant effect of the same fungicide.

It is notable that the strongest advantage in percent germination was conferred by the lower concentrations of fungicides used in both Experiments 2B and 2D (Tables 2.2, 2.4). This suggests that high levels of benomyl thiram, and Terrazole may be phytotoxic and that the poor results of others may be as a result of excessive concentration of fungicide. An apparent delay in germination as a result of Terrazole treatment observed in Experiment 2B (Table 2.2) was not confirmed by Experiment 2D (Table 2.4). The advantage conferred by fungicidal treatments will, of course, vary according to the microflora present.

Further work may be necessary to determine the most suitable levels of these fungicides, but it seems reasonable to recommend their continued use at low levels as a precautionary measure.

Hypochlorite surface disinfection was used as a general precautionary measure in Experiments 2A, 2C, and 2D. This practise has been recommended by Neuray (1971d) and Anderson and Widmer (1975) but Experiment 2B (Table 2.2) suggests that a more detailed investigation might show significant reductions and delay in germination. Neuray (1971d) did report a delay in germination as a result of this treatment.

CHAPTER THREE

THE INFLUENCE OF N, P, K, AND LIMING ON GROWTH AND FLOWERING OF CYCLAMEN PERSICUM MILL

3.1 Abstract

C. persicum responded to very high levels of N, P, K, and Lime. N strongly influenced foliage growth, corm development, and flowering these effects often being modified by P, K, and Lime additions. P additions enhanced flower quality and number particularly where K was also increased. Increases in K tended to depress corm growth. A number of interactions between nutrients were found.

3.2 Introduction

Previous studies of the nutrition of *Cyclamen persicum* used simple proprietary mixed or slow release fertilisers (Burghardt, 1972; Gugenhan, 1969ab; Otto, 1968, 1969; Schwemmer, 1976, 1977; Soupcoup Matous, 1974; Tepe, 1968, 1970; Turner, 1973) or the main effect of single nutrients (Freisdorf, Vershenstalt, 1973; Miura, 1968). Rarely were fertilisers quantified in terms of available nutrients and in no cases had the interactions between the nutrients been investigated.

The objective was to examine the influence of N, P, and K fertilisation and liming (L), and to study their interactive effects within a single experiment. A second experiment was carried out after

this experiment to study the effect of unusually high levels of N, P, K, and L.

MATERIAL AND METHODS

3.3 Experimental Design

Box and Hunter (1957) proposed the rotatable central multifactor composite design used in these experiments (also described by Chochran and Cox, 1957). This design yields a high level of information and has been used for nursery plant research by Thomas (1979); Lai, Thomas, and Love (unpublished), Khoo (1979).

Four factors N, P, K, and L were combined in 30 treatments arranged in ten and seven blocks for Experiments 3A and 3B, respectively. The blocks were divided into three sub-blocks. The treatment nutrient levels are given in Table 3.1.

Table 3.1. The Levels of N, P, K, and L Applied in Trials 3A and 3B in g m^{-3} of Soil (for N, P, K) and Kg m^{-3} of Soil (L).

Nutrient	N		P		K		L	
Experiment	A	B	A	B	A	B	A	B
Level Name								
-2	0	0	0	0	0	0	0	0
-1	150	300	100	200	83	166	3	6
0	300	600	200	400	166	332	6	12
1	450	900	300	600	250	498	9	18
2	600	1200	400	800	332	664	12	24

3.4 Fertilisers

The fertilisers were the same as or similar to those in common New Zealand nursery use. Nitrogen was supplied from Osmocote 26% N applied equally as a basal dressing and a side dressing after three months. All other nutrients were included in the medium at laying down. Phosphorus and Potassium were supplied respectively from superphosphate 8% P in 3A and 9% P in 3B and sulphate of potash (39% K). Lime was supplied as agricultural lime (CaCO_3) one part to three parts (w:w) dolomite. The following ingredients at fixed levels were common to all treatments: 75 g m^{-3} sequestrene iron chelate (NaEdTAFE 12% Fe), 150 g m^{-3} sporumix (1.14% B, 5.46% Mn, 0.06% Mo, 0.05% Co, 9.78% Mg, 0.62% Zn, 1.27% Cu).

3.5 Plant Material and Potting Medium

Three monthold seedlings of *Cyclamen persicum* Mill ('Bonfire' for Experiment 3A and mixed varieties for Experiment 3B) were potted into a medium containing 50% Springhill peat and 50% (v.v.) coarse manufactured sand. Experiment 3A was potted on 1st September, 1977, into bags (PB3) containing 1.8 l of mix. Experiment 3B was potted on 4th August, 1978, into plastic 15 cm pots containing 1.4 l of mix. The physical and chemical characteristics of the sand and a similar southland peat (Mataura) have been described by Goh and Haynes (1977) and the influence of fertilisers used on the peat sand medium is detailed in Appendix I.

3.6 Growing Conditions

The plants were grown in heated automatically ventilated glasshouses with a minimum temperature of 15°C and a maximum of 5°C

above ambient. At the end of November the plants were moved to a Sarlon 50% shade house where temperatures ranged between 5 °C and 37 °C. The following April plants were replaced in the greenhouse. Watering was by hand as required.

3.7 Plant Protection

The medium had been disinfected with methyl bromide. Terrazole (35 g a.i. m^{-3}) and benomyl (10 g a.i. m^{-3}) were included in the medium as a precaution against *Nectria radicola*, *Botrytis cinerea* and *Fusarium oxysporum* f. sp. cyclaminis. The medium for Experiment 3B contained Deildrin (19.5 g a.i. m^{-3}) to combat black vine weevil (*Otiiorhynchus sulcatus* F.).

A regular spray program of benomyl (75 g a.i. l^{-1}) alternated every seven to ten days with captan (125 g a.i. l^{-1}) as a precaution against *Botrytis cinerea*. A general insecticide (Maldison) was included with these sprays.

3.8 Data Collection and Analysis

Assessments made are listed with the results in Table 3.2 and 3.3. Chlorophyll content was assessed as described by Khoo (1970). Randomly selected leaf tissue samples of known area and fresh weight were ground in 80% acetone, filtered, and the optical density measured at 652 nm. These readings were used directly as a relative measure of chlorophyll content without using the calculation derived by Arnon (1949) which converted these readings to chlorophyll per litre. These readings were expressed as relative chlorophyll content per unit area, and per gram fresh weight.

Foliar nutrient levels were assessed from oven dried material after digestion in $\text{H}_2\text{O}:\text{H}_2\text{SO}_4$. Nitrogen content was measured by autoanalysis and P by calorimetric methods and K, Ca, and Mg by atomic absorption photospectrometry as described by Parkinson and Allen (1975).

Plant width and corm diameter were taken as the average of two perpendicular measurements.

Foliage and flower height were respectively the maximum height of foliage and flowers above the corm. In Experiment 3A petiole length and its diameter and the widest part were the mean of five leaves or flowers randomly selected from each plant at harvest.

For convenience a number of data were measured using arbitrary scalings from 1 - 5. These are on an increasing scale, for example, 5 being allotted to the deepest green or the largest flower when foliage colour and flower size were being rated respectively. Data was processed using Boxhu computer program (available from Lincoln College) to calculate quadratic response surfaces and two factor interactions.



ON 300 g N m⁻³ 600 g N m⁻³

Plate 1. Experiment 3A. Influence of N on Growth and Flowering of *C. Persicum*.



OP 200 g P m⁻³ 400 g P m⁻³

Plate 2. Experiment 3A. Influence of P on Growth and Flowering of *C. Persicum*.

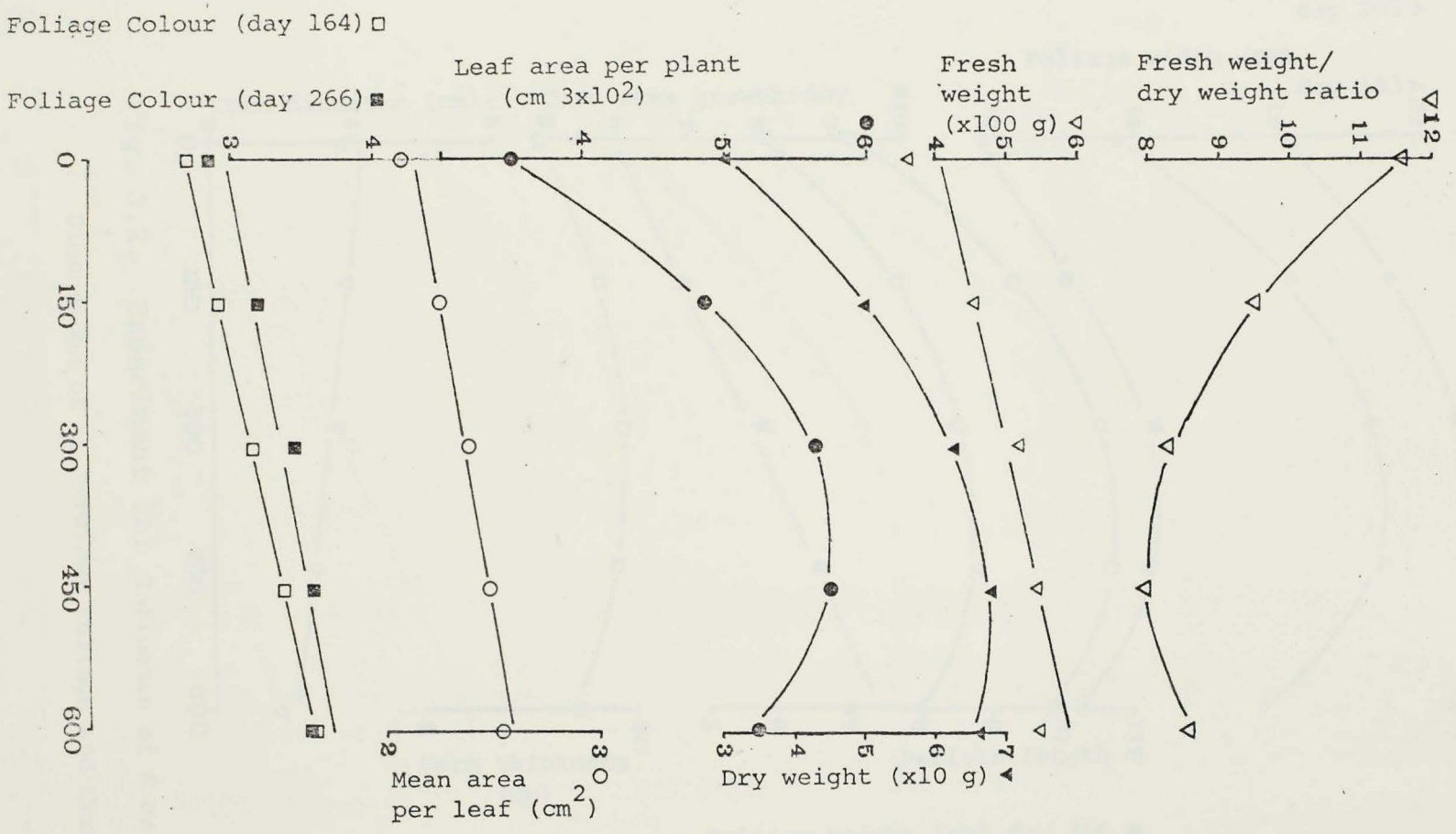


Fig. 3.1. Experiment 3A: Influence of N fertilisation on Foliage Growth.

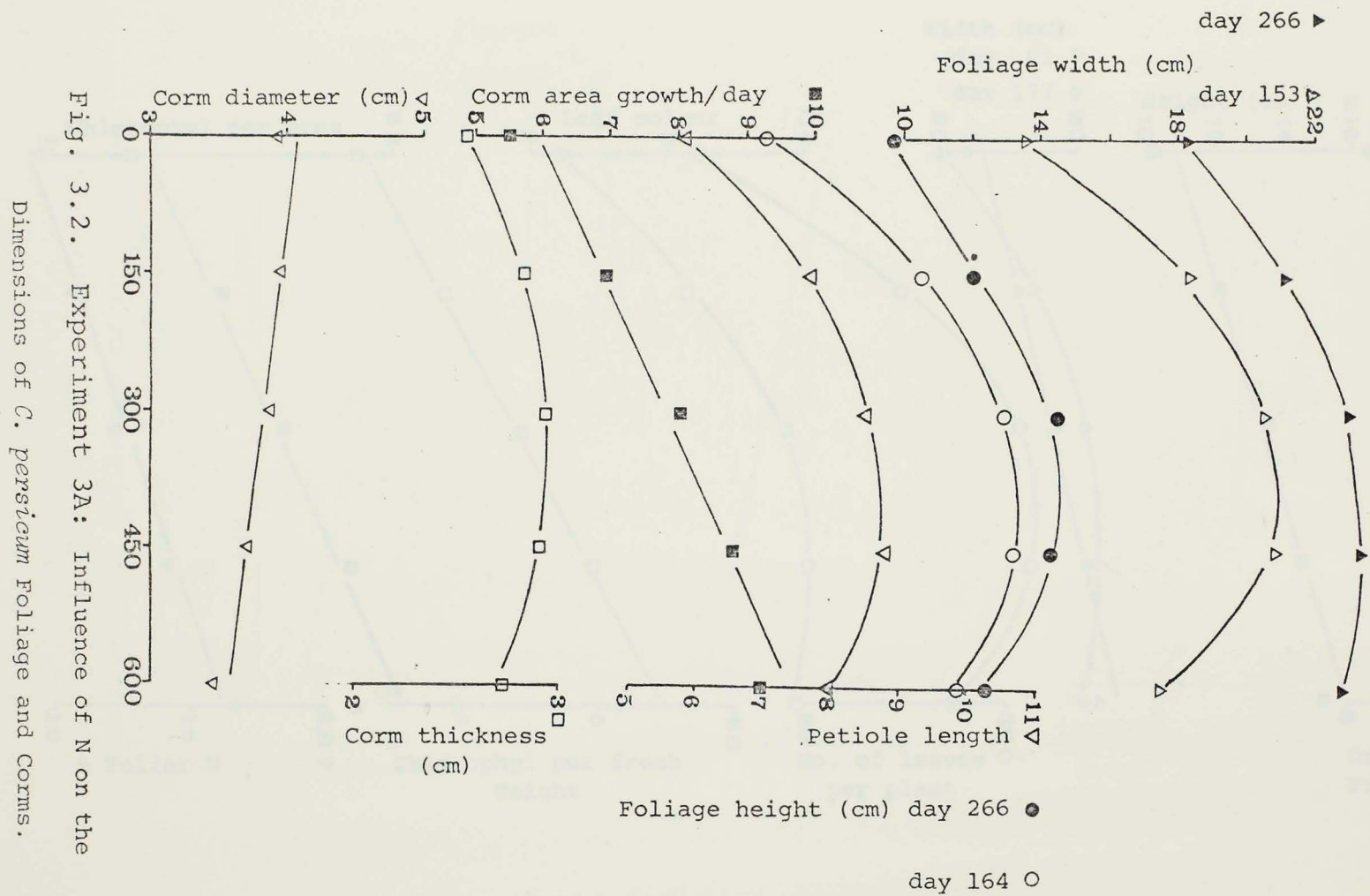
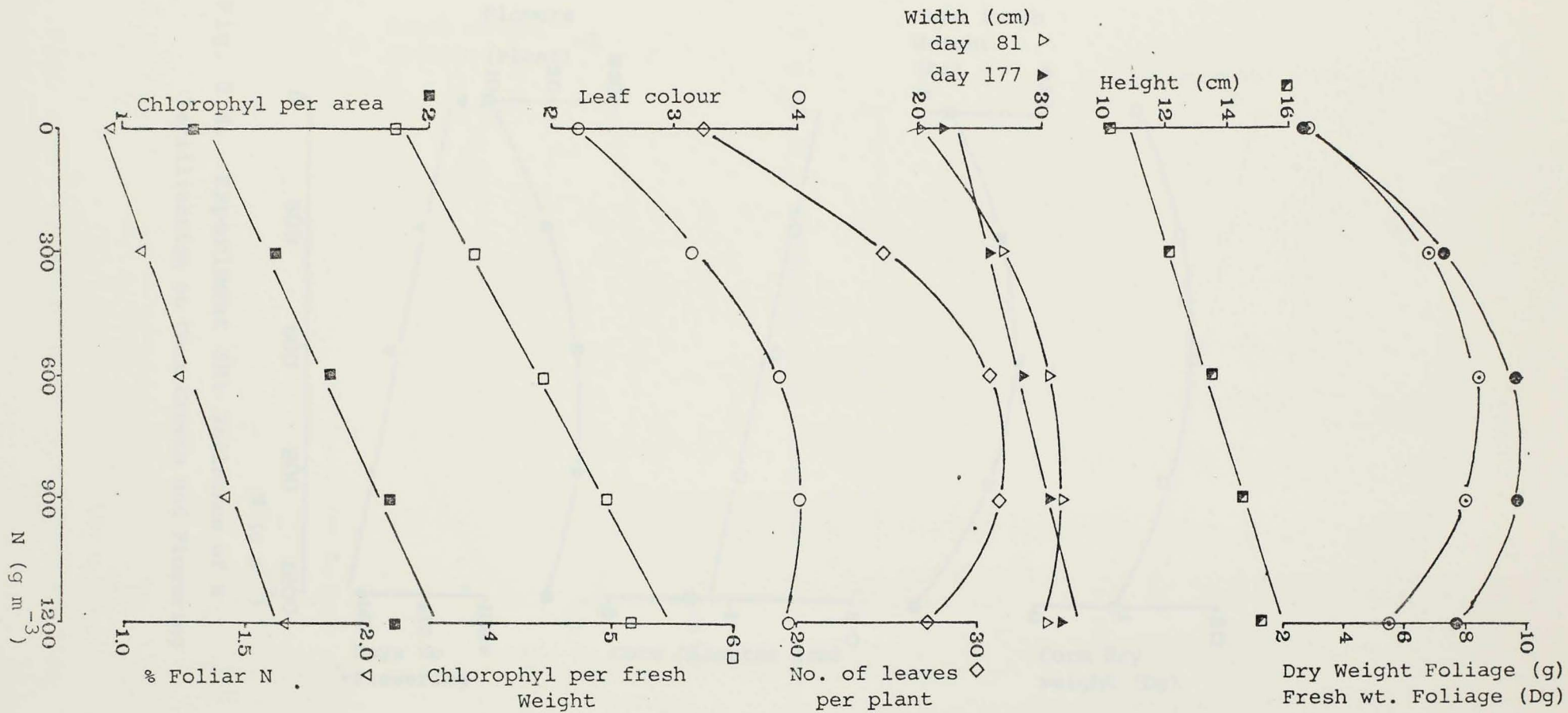


Fig. 3.2. Experiment 3A: Influence of N on the

Dimensions of *C. persicum* Foliage and Corms.

Fig. 3.3. Experiment 3B: Influence of N
Fertilisation on Foliage Growth



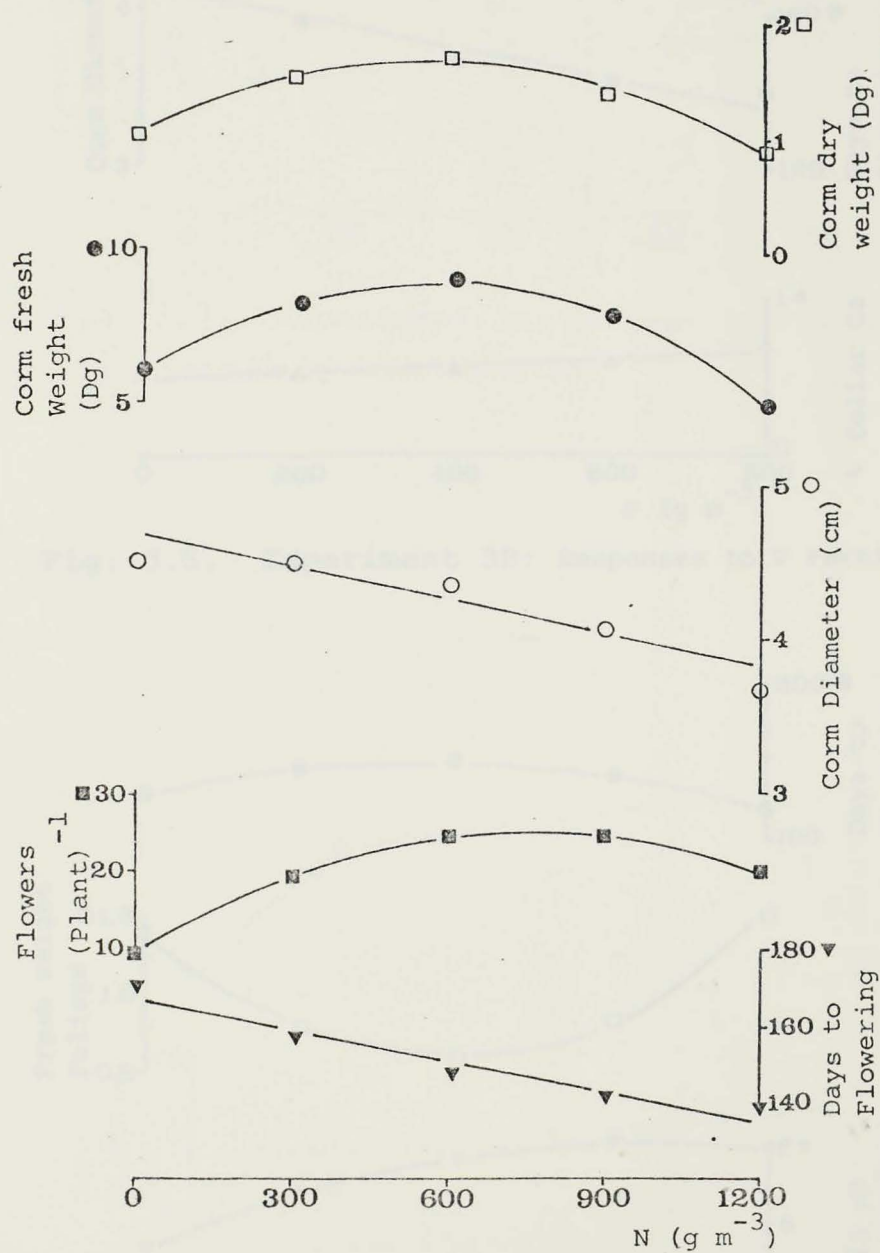


Fig. 3.4. Experiment 3B: Influence of N Fertilisation on Corm Growth and Flowering

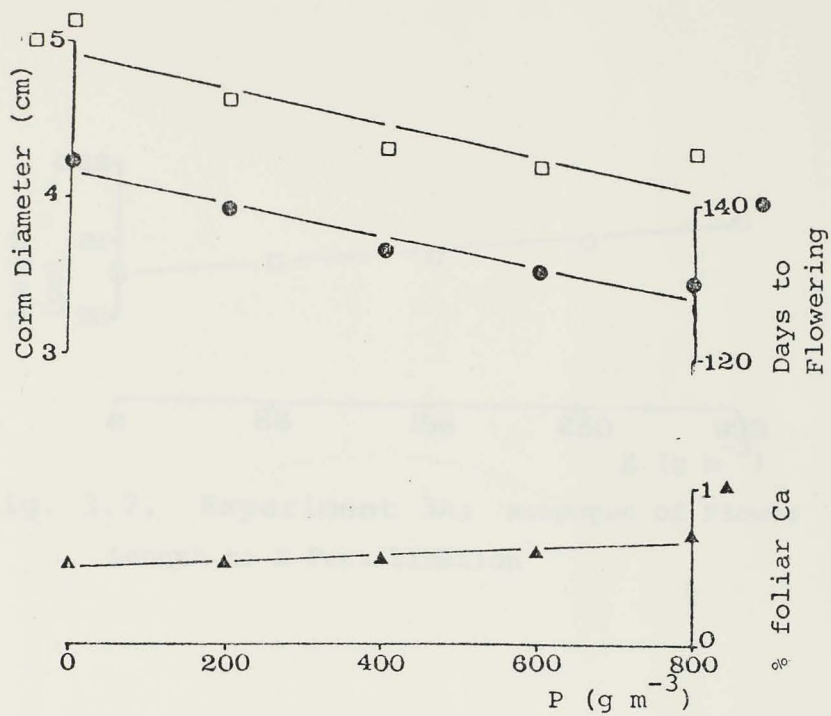


Fig. 3.5. Experiment 3B: Responses to P Fertilisation

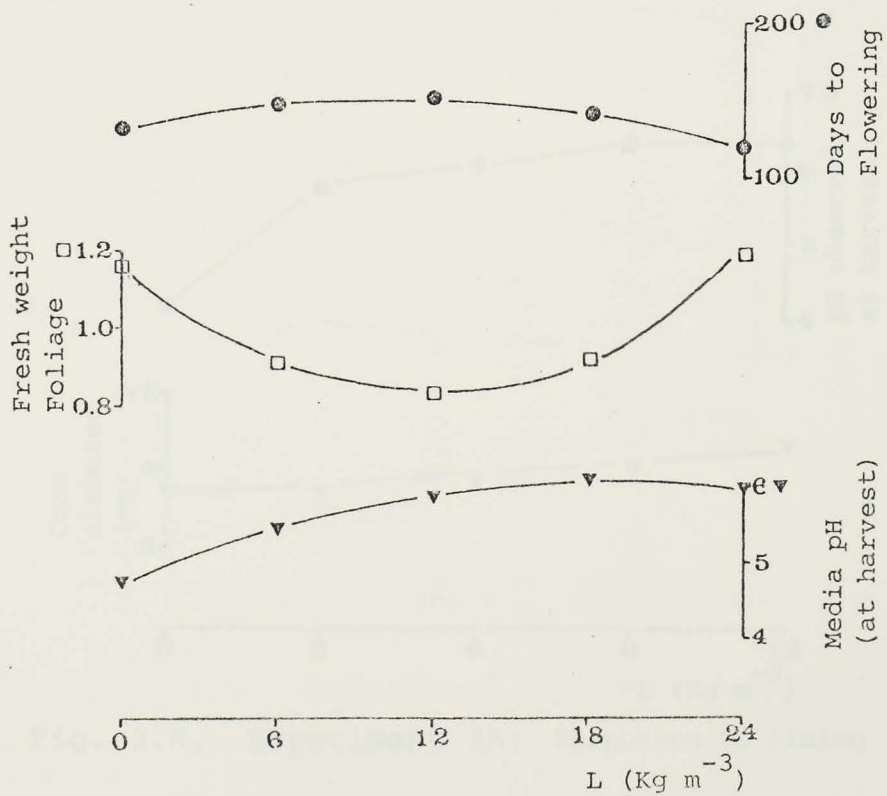


Fig. 3.6. Experiment 3B: Responses to Liming

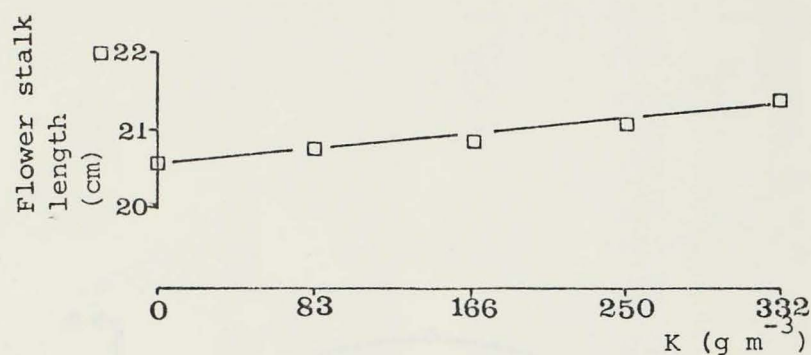


Fig. 3.7. Experiment 3A: Response of Flower Length to K Fertilisation

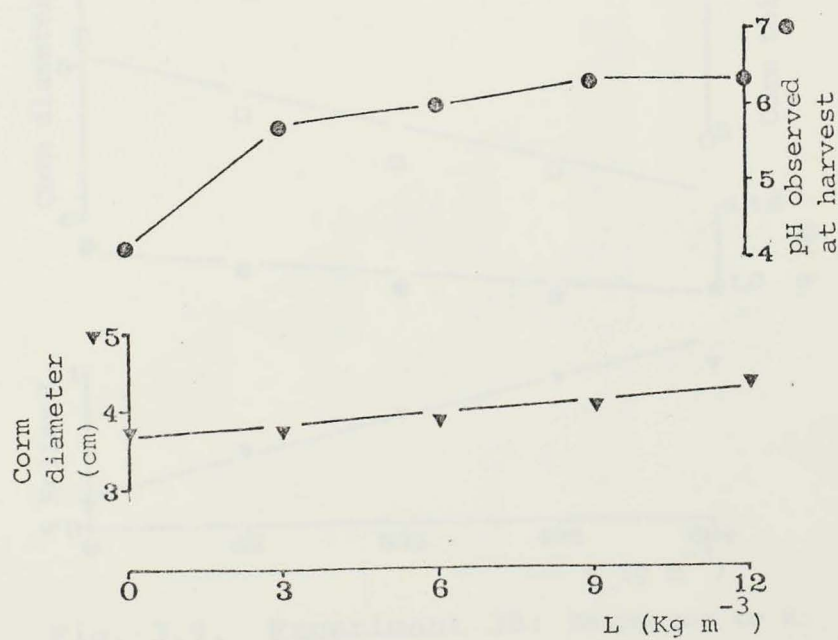


Fig. 3.8. Experiment 3A: Responses to Liming



Fig. 3.9. Experiment 3B: Responses to K Fertilisation

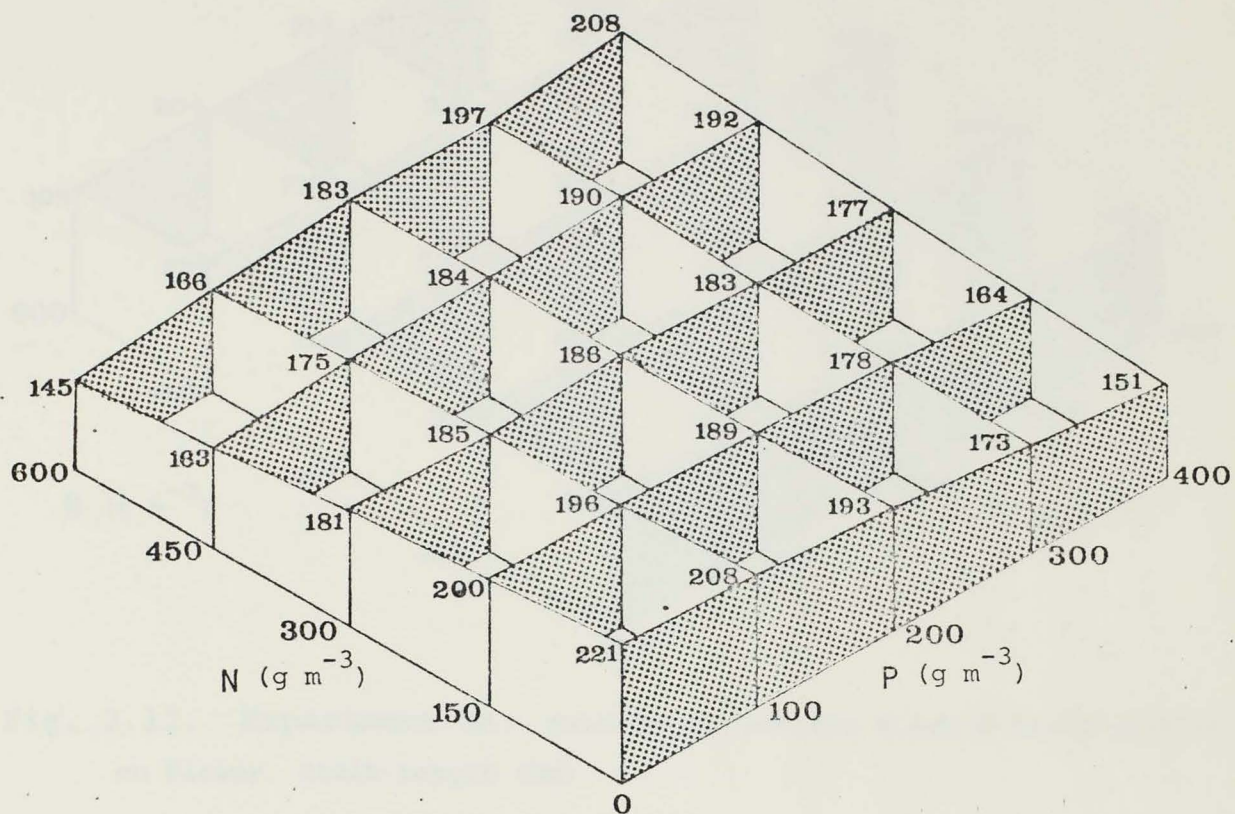


Fig. 3.10. Experiment 3A: Interaction Between N and P Fertilisation on Number of Days to Flowering

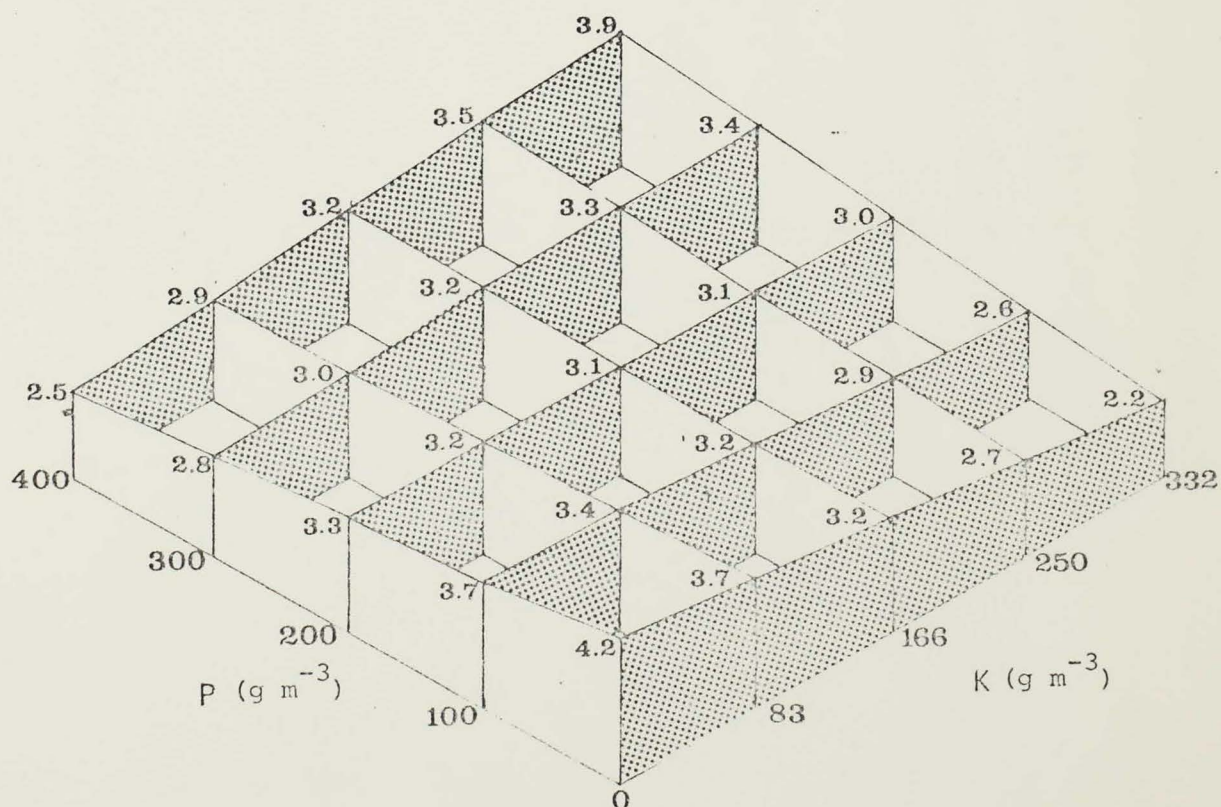


Fig. 3.11. Experiment 3A: Interaction Between P and K Fertilisation on Foliage Colour

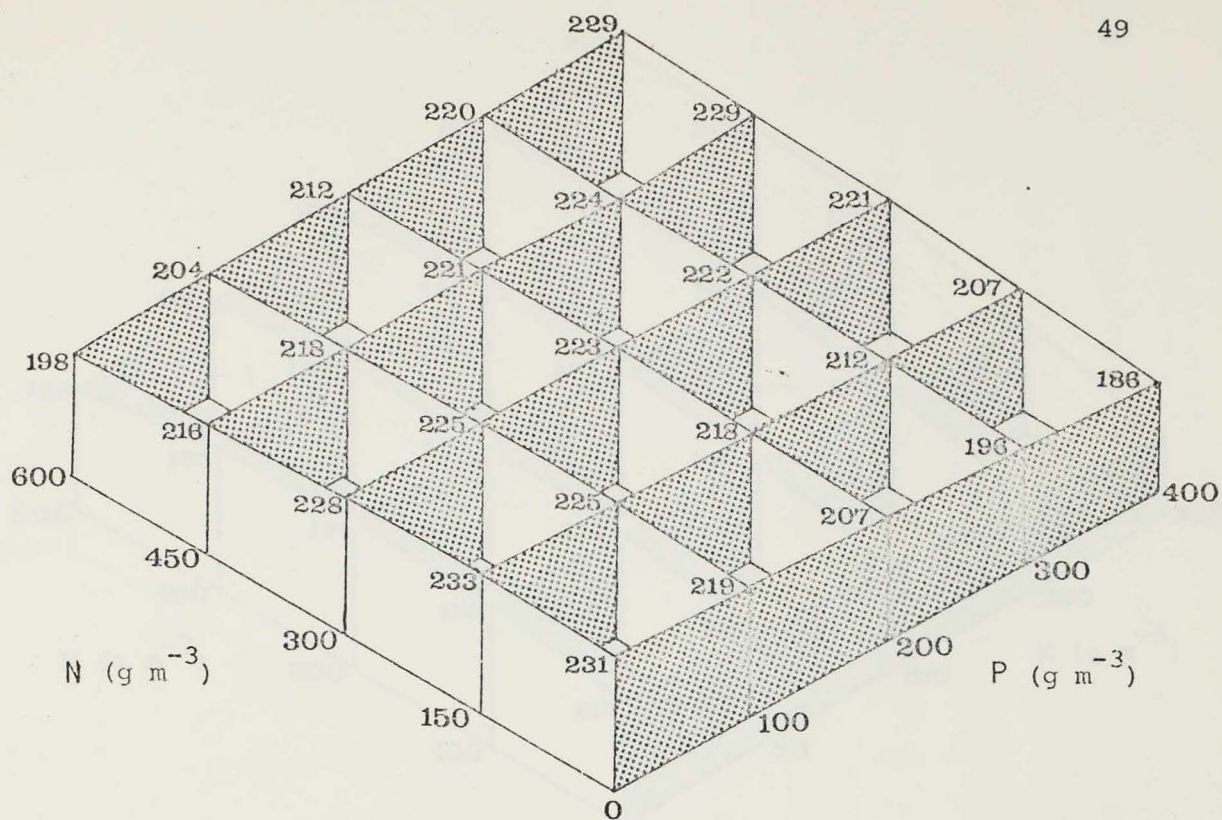


Fig. 3.12. Experiment 3A: Interaction Between N and P Fertilisation on Flower Stalk Length (mm)

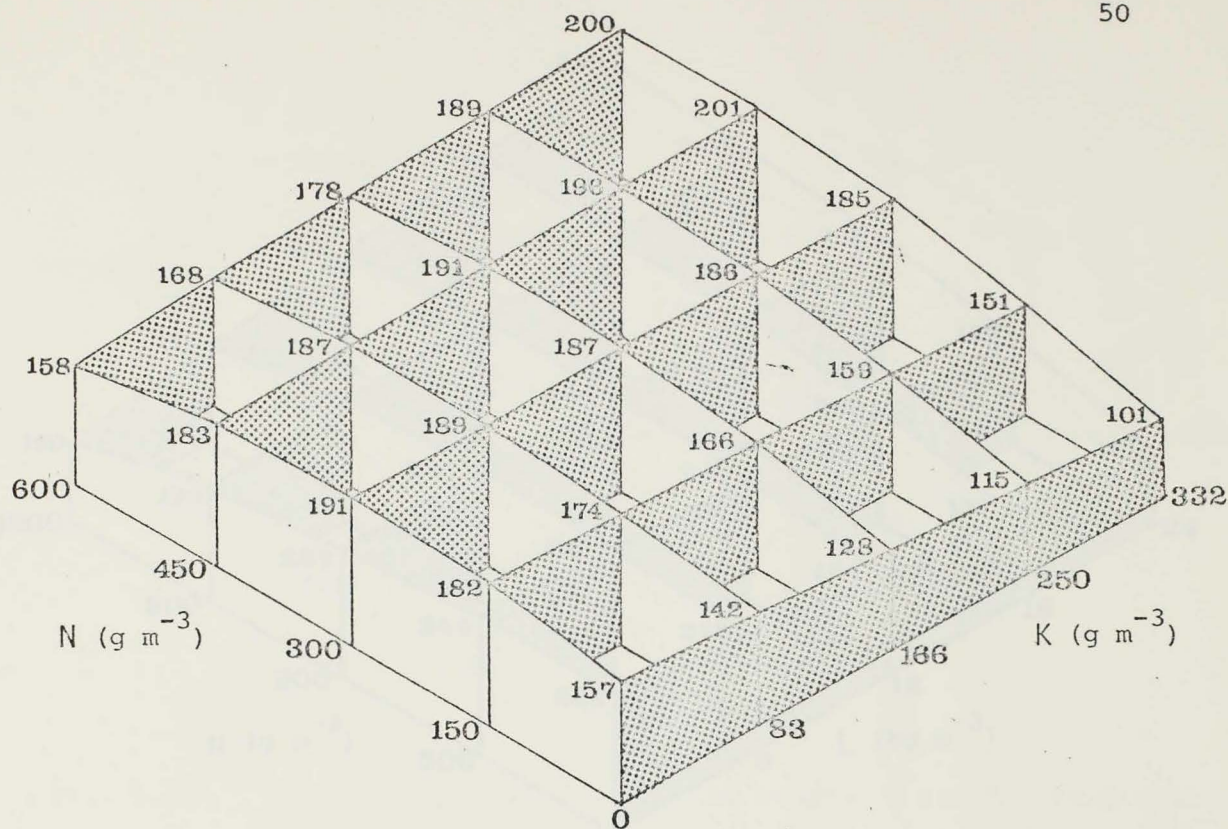


Fig. 3.13. Experiment 3A: Interaction Between N and K Fertilisation on Plant Width (mm) Before Flowering (day 153)

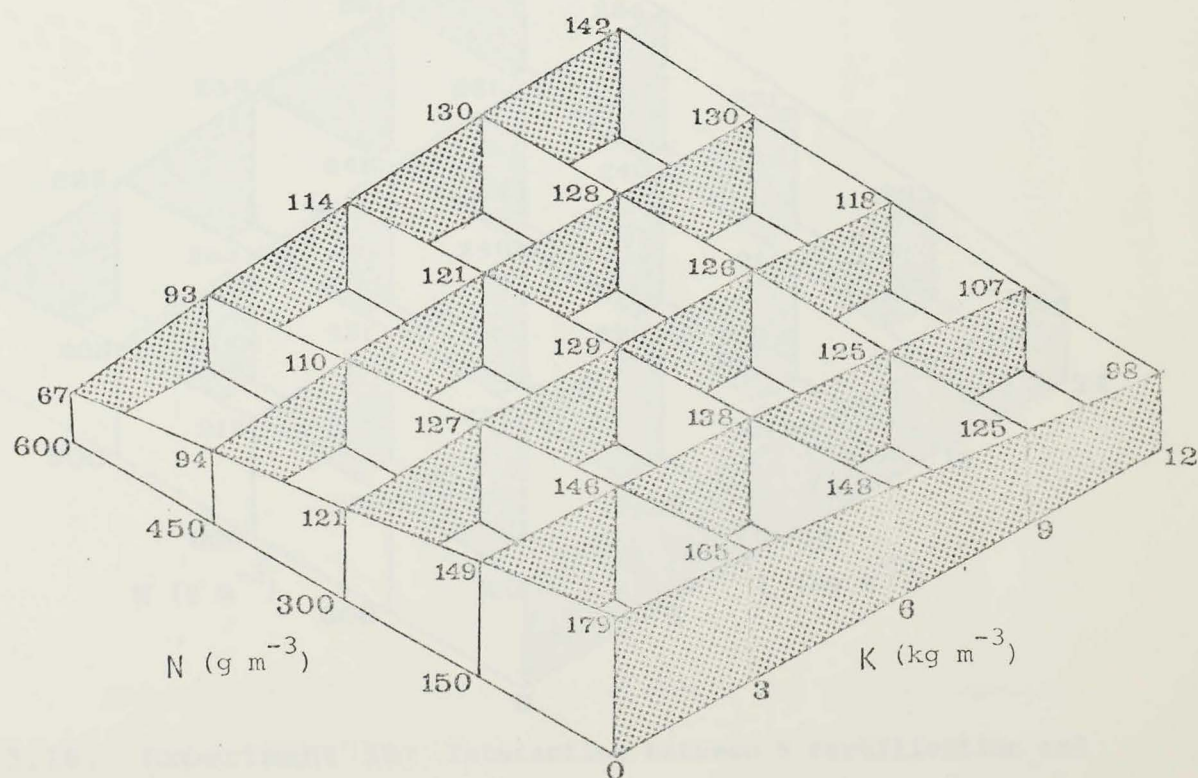


Fig. 3.14. Experiment 3A: Interaction Between N Fertilisation and Liming on Maximum Root Length (mm)

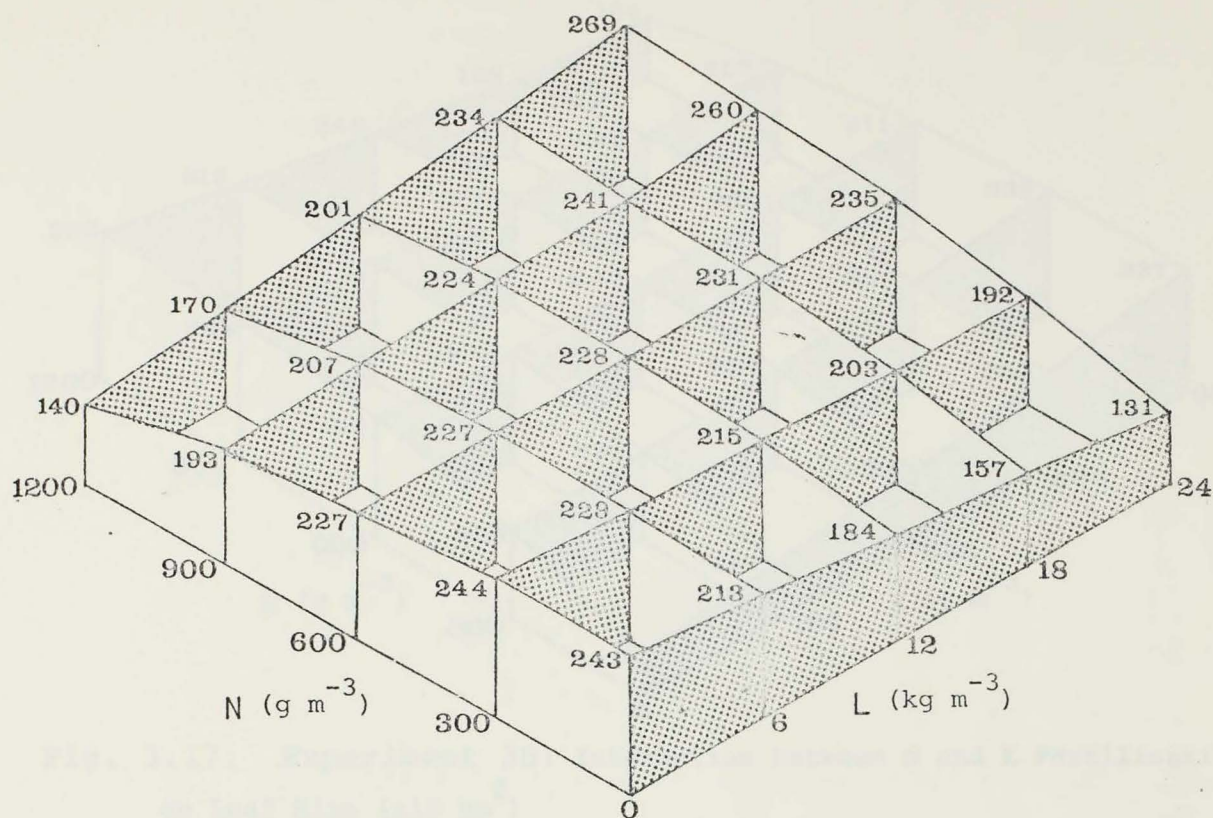


Fig. 3.15. Experiment 3B: Interaction Between N Fertilisation and Liming on Dry Weight per Flower (mg)

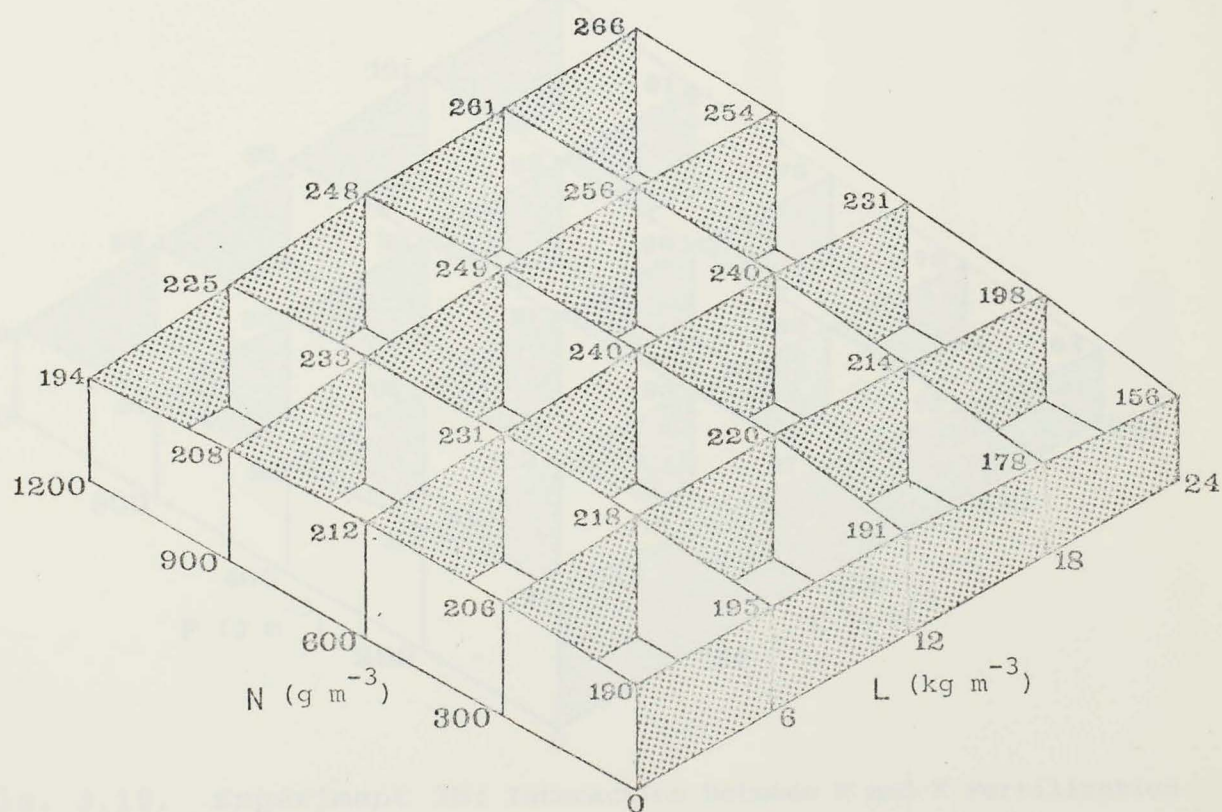


Fig. 3.16. Experiment 3B: Interaction Between N Fertilisation and Liming on Flower Dry Weight (mg)

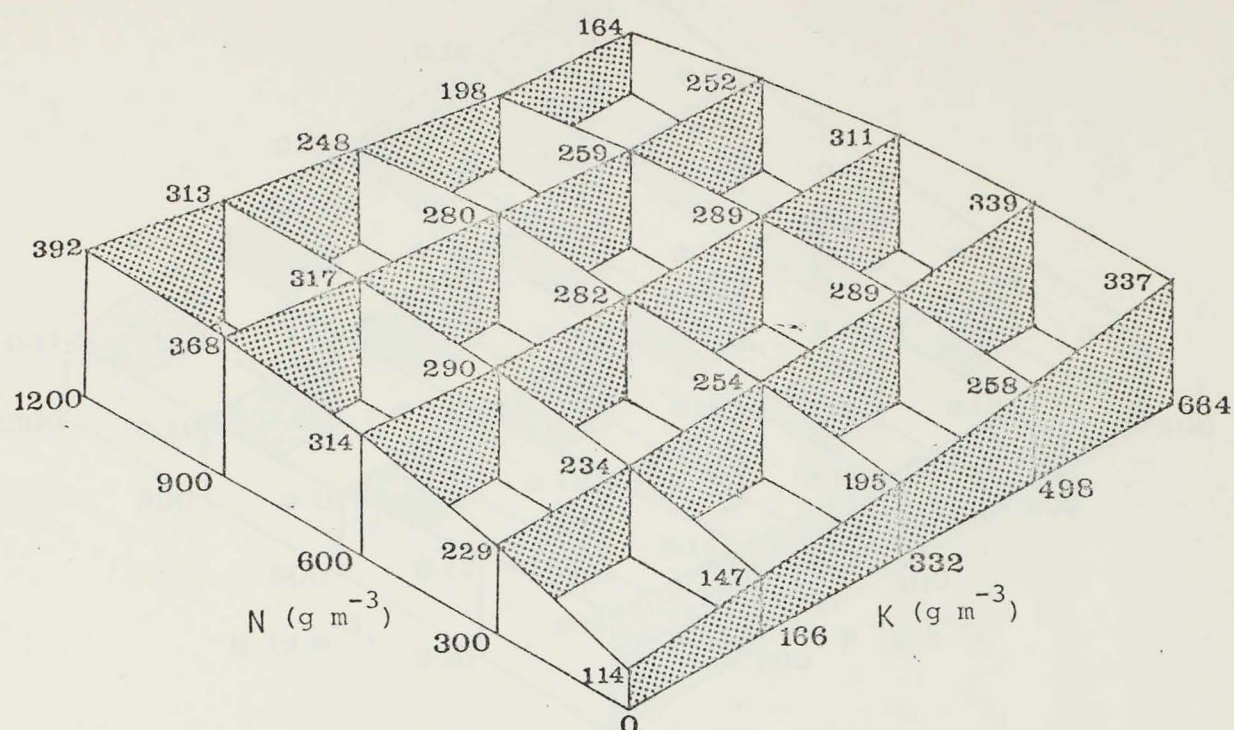


Fig. 3.17. Experiment 3B: Interaction Between N and K Fertilisation on Leaf Size ($\times 10 \text{ mm}^2$)

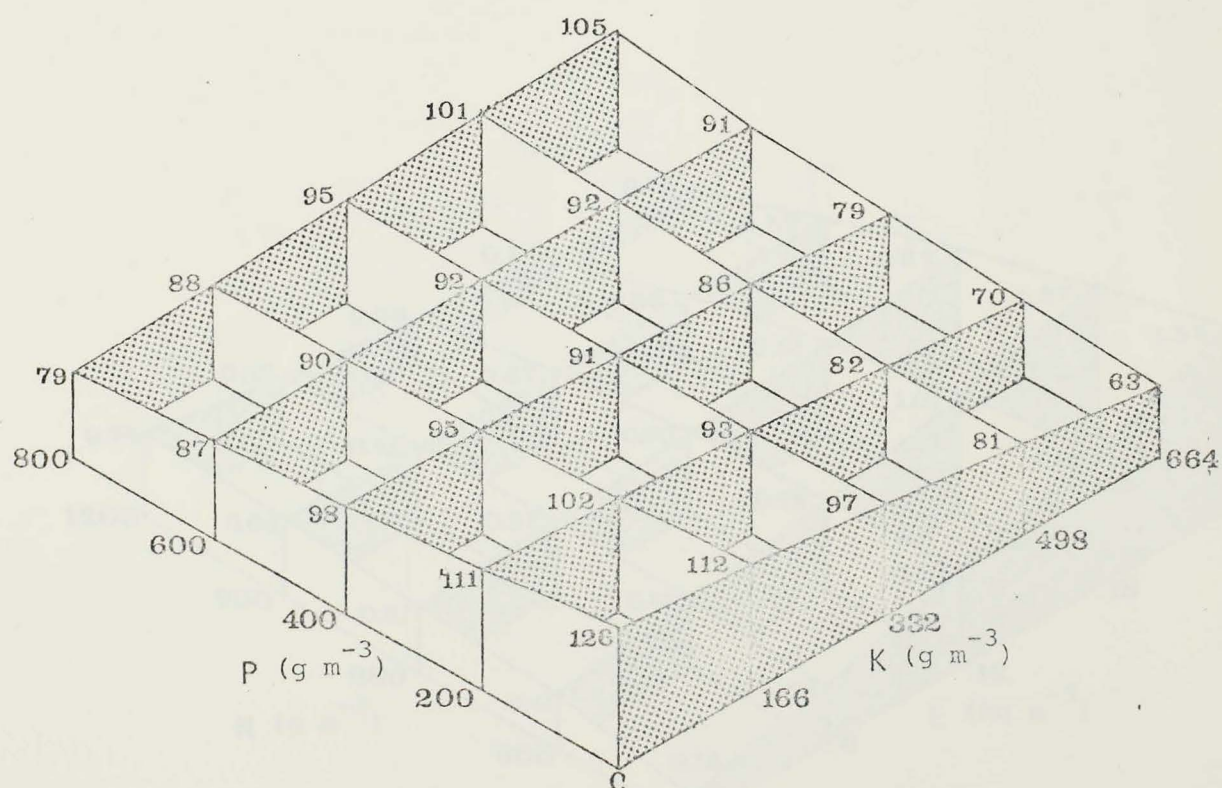


Fig. 3.18. Experiment 3B: Interaction Between P and K Fertilisation on Corm Fresh Weight (g)

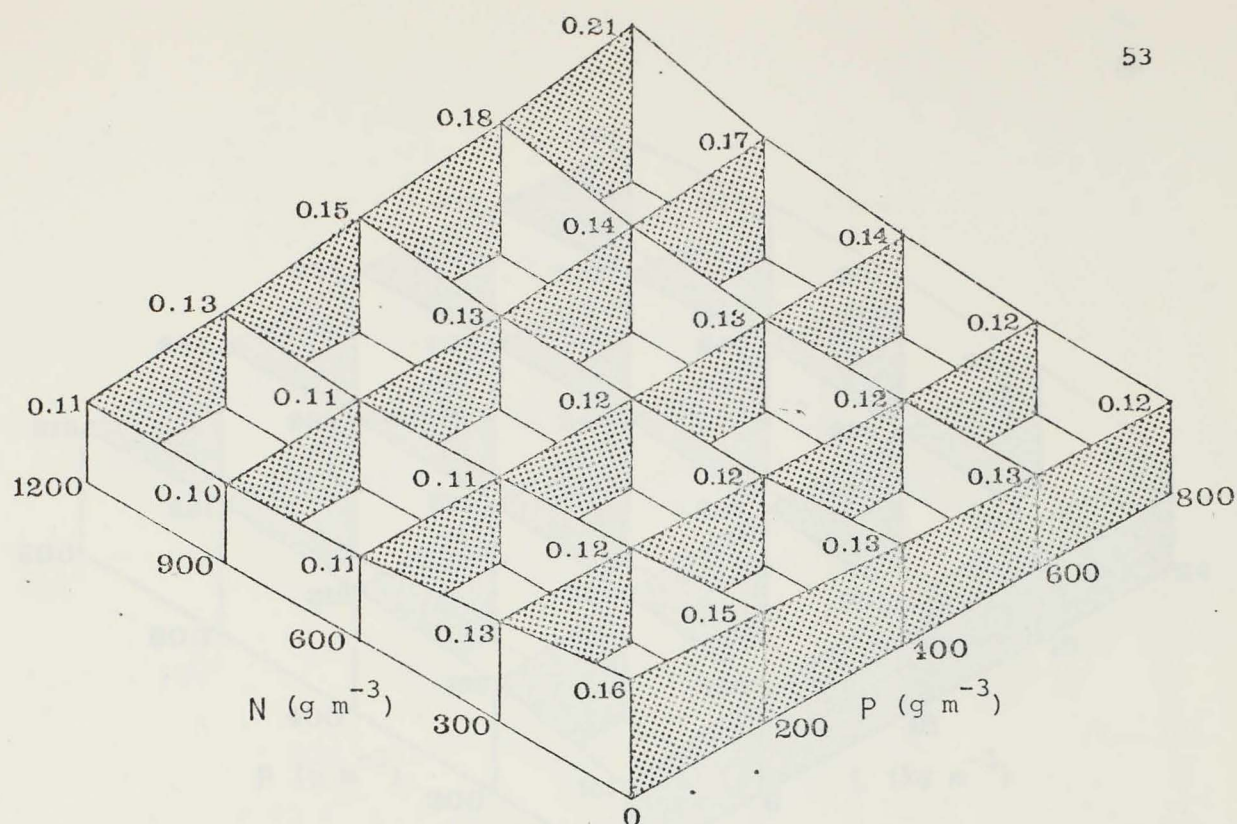


Fig. 3.19. Experiment 3B: Interaction Between N and P Fertilisation on Foliar P Levels (%)

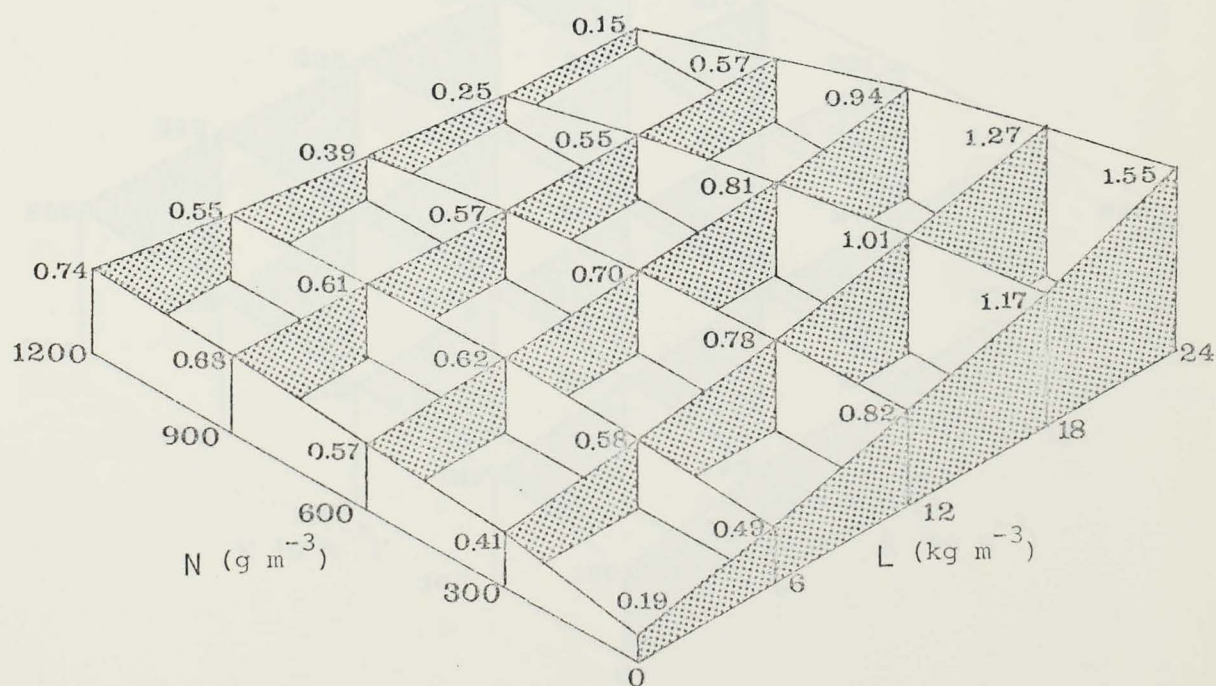


Fig. 3.20. Experiment 3B: Interaction of N Fertilisation and Liming on Foliar K Levels (%)

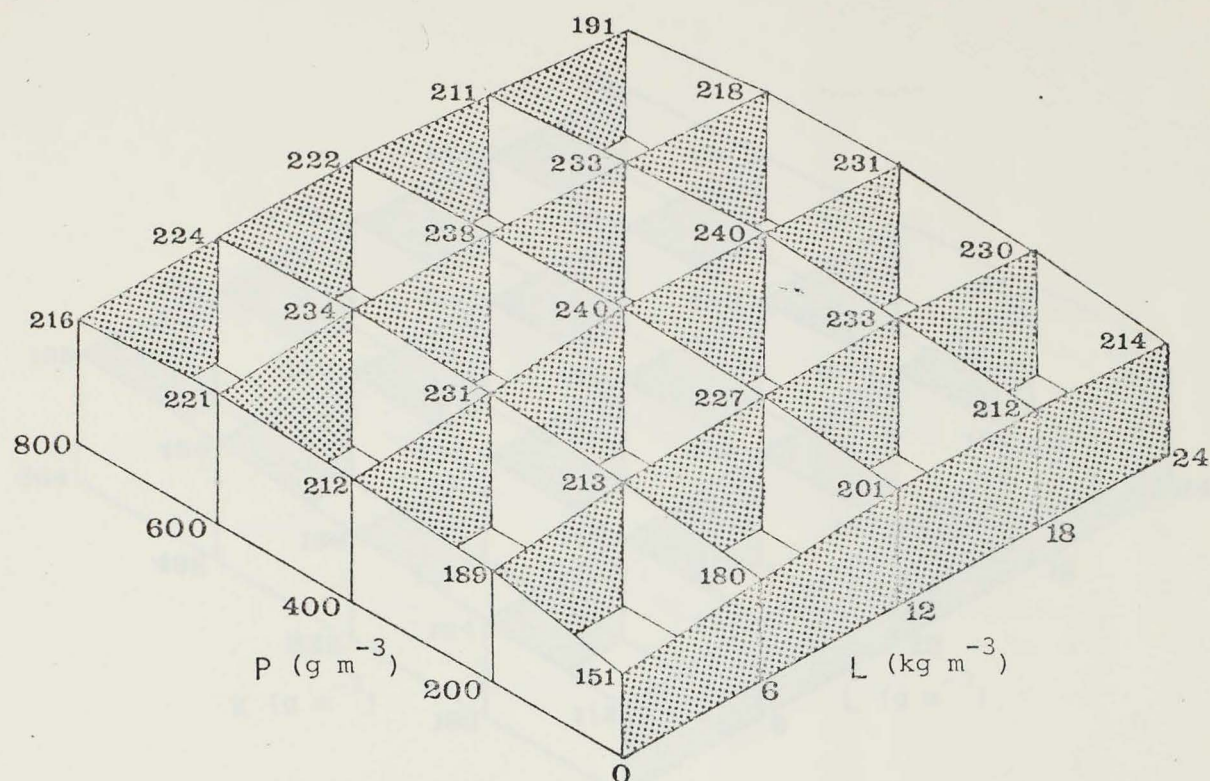


Fig. 3.21. Experiment 3B: Interaction Between P Fertilisation and Liming on Height of Flowers (mm)

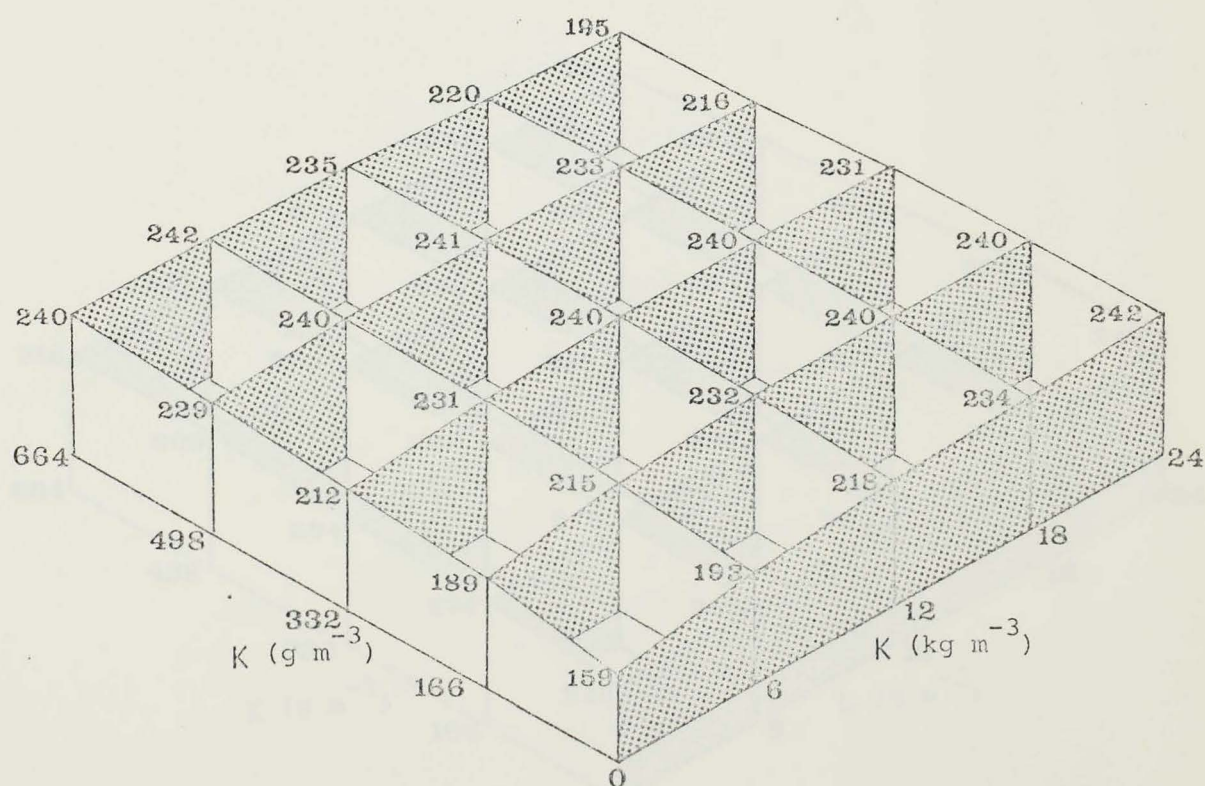


Fig. 3.22. Experiment 3B: Interaction Between K Fertilisation and Liming on Height of Flowers (mm)

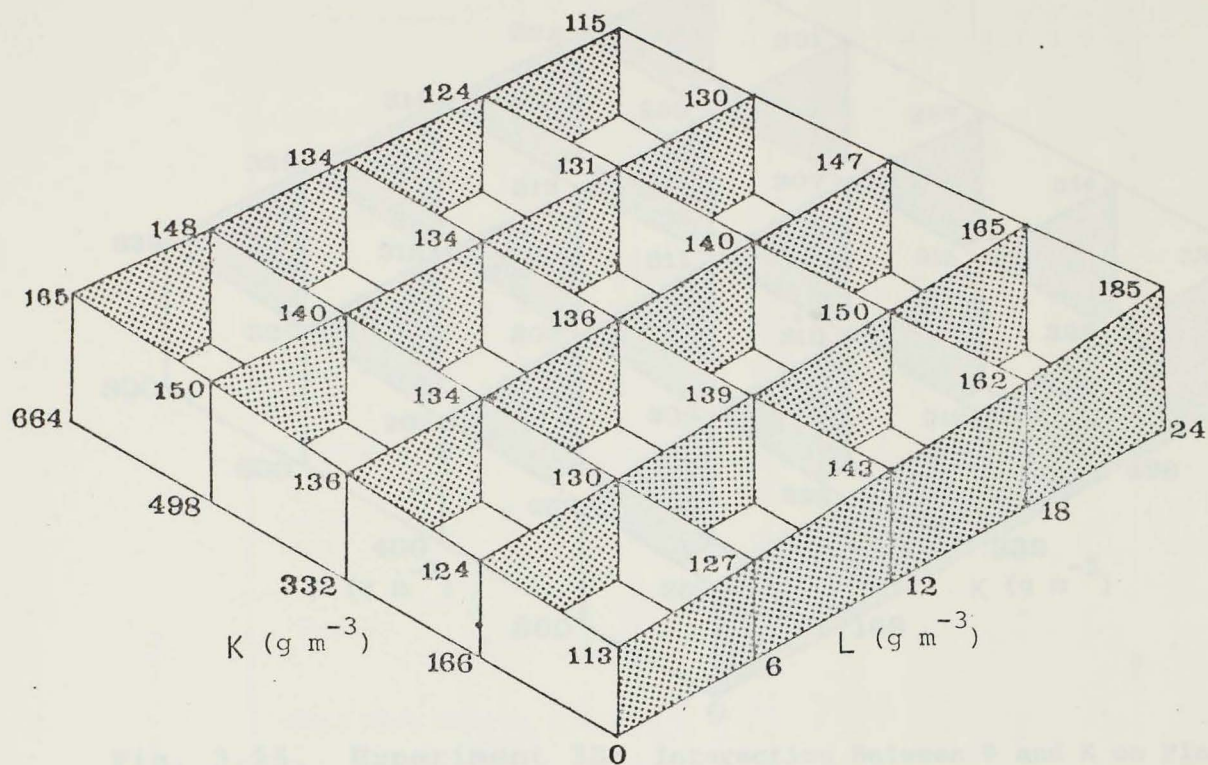


Fig. 3.23. Experiment 3B: Interaction Between K and L Fertilisation on Foliage Height (mm) Prior to Flowering (day 69)

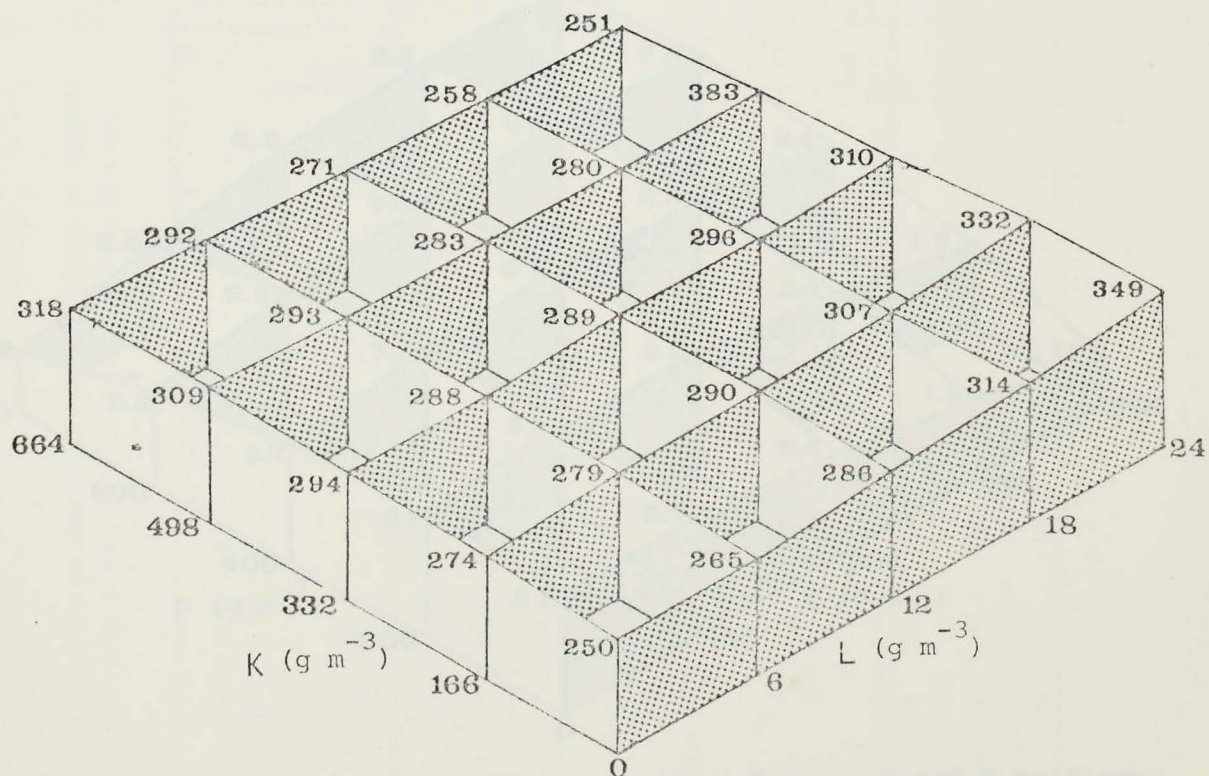


Fig. 3.24. Experiment 3B: Interaction Between K and L Fertilisation on Foliage Width (mm) Prior to Flowering (day 81)

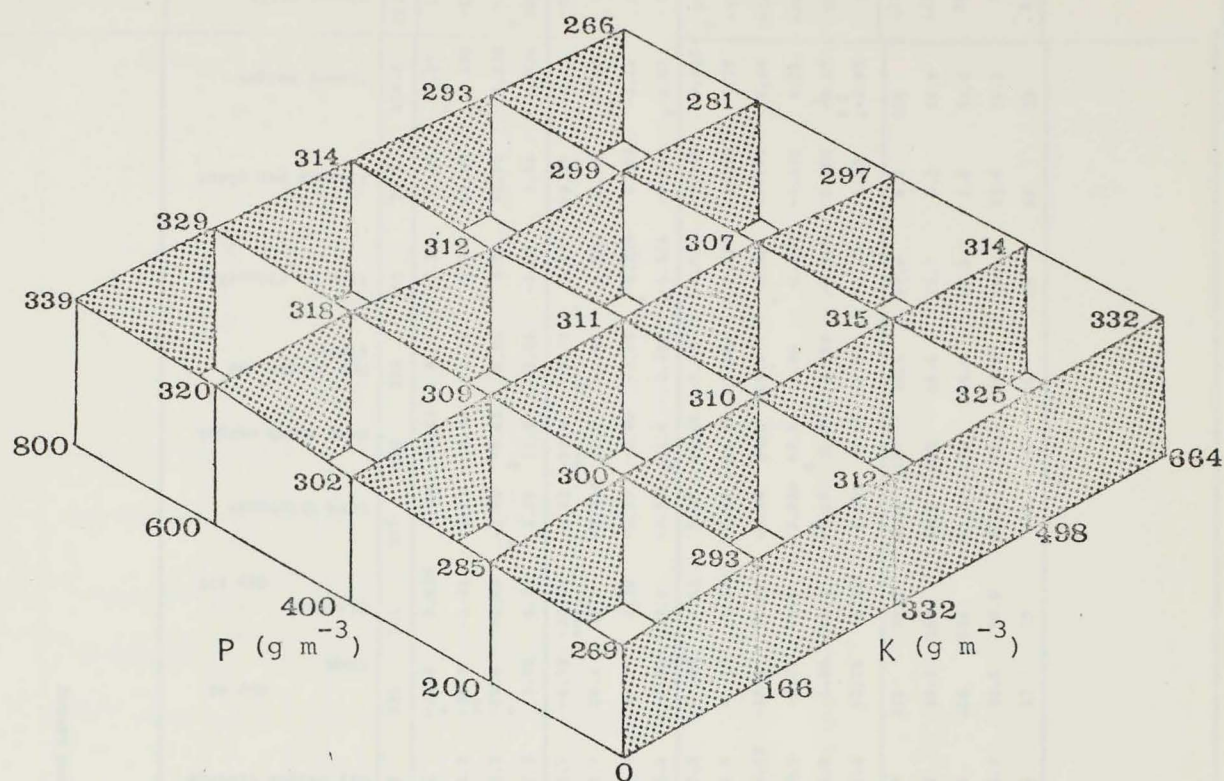


Fig. 3.25. Experiment 3B: Interaction Between P and K on Plant Width (mm) at Harvest

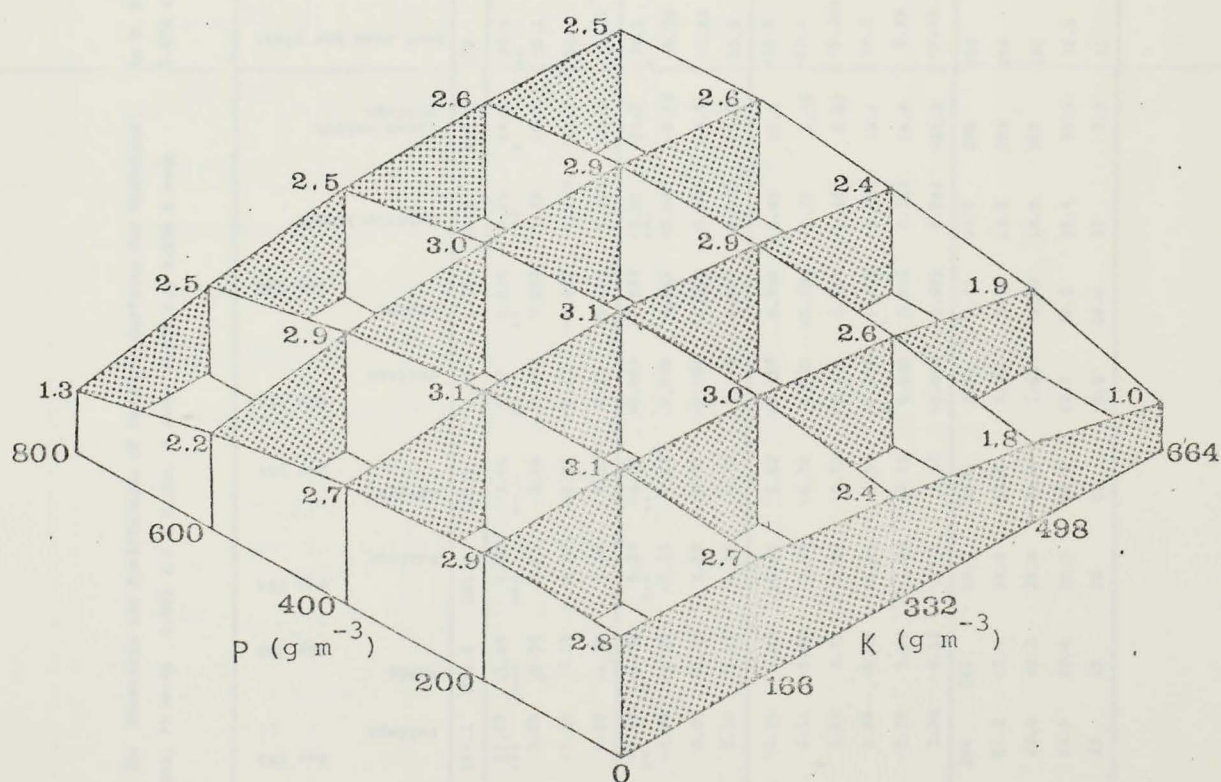


Fig. 3.26. Experiment 3B: Interaction Between P and K on Flower Size (arbitrary scale 1-5)

Table 3.2. Experiment 3A: Constants and Coefficients of Response Surfaces for Responses

to N, P, and K Fertilisation and Liming

*** \rightarrow $P < 0.001$, ** \rightarrow $0.001 \leq P < 0.010$, * \rightarrow $0.010 \leq P < 0.050$ # \rightarrow $0.050 \leq P \leq 0.100$

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	day 153 Foliage	day 266 Width	day 164 Foliage	day 266 Height	day 164 Foliage	day 266 Colour	Petiole length	Fresh weight foliage	Leaf area per plant	Area per leaf	Fresh weight foliage	Dry weight foliage	day 81 Corm	day 177 Diameter	Corm thickness	Corm fresh weight	Dry weight per flower	Time to flowering	Flowers per plant	Flower height	Flower stalk length	Flower stalk diameter
Constant	187.1	231.6	105.4	113.1	3.45	3.15	86.0	520.8	274	282	839	948	434	715	299	914	228	148	24.0	239.8	2230	455
N	12.47	11.85	7.05	3.66	0.20	0.238	5.46	46.2	38.4	13.2	67.3	126	-19.8	0.940	0.006	-9.43	4.31	-7.52	2.50	14.27	12.2	3.29
P	2.22	5.04	0.21	2.10	0.058	0.004	1.48	14.0	15.1	0.583	80.2	45.7	-20.2	-2.45	1.63	-5.70	1.72	5.35	-1.08	5.250	-15.3	-0.79
K	-1.65	1.71	0.76	-0.37	-0.13	-0.071	0.925	13.3	12.7	-0.750	38.1	46.3	-18.2	-9.90	-7.85	-4.61	5.56	3.99	-1.75	4.238	53.4	-3.96
L	4.07	0.69	1.46	0.35	0.11	-0.113	0.325	15.3	1.17	-12.1	12.0	37.3	4.22	6.75	3.09	17.5	2.06	-2.39	1.50	4.726	182	5.46
N ²	-8.48	-6.32	5.27	-4.22	-0.060	-0.007	-3.99	-14.7	-30.1	15.2	-10.7	-10.7	-6.72	-33.6	-4.61	-97.8	-8.78	1.68	-2.35	-5.13	-33.9	-8.95
P ²	-4.05	-0.57	-2.13	1.00	0.040	0.018	-0.665	-2.92	-9.30	9.06	44.1	-26.7	10.4	10.7	-0.418	11.3	-2.91	0.503	-1.10	-7.17	4.40	-0.698
K ²	-0.20	-0.73	0.07	0.71	-0.085	-0.007	0.460	-3.41	-5.93	7.56	-39.1	-19.9	11.9	2.75	-2.19	-6.80	-3.20	-0.515	0.396	-3.22	5.40	-1.95
L ²	2.39	2.15	1.77	-0.74	-0.048	0.107	0.077	11.7	10.6	10.31	85.9	57.1	-5.75	14.9	-3.79	41.6	0.799	-5.515	-0.604	-4.53	2.27	7.55
N x P	-0.71	5.43	-0.43	1.62	-0.113	0.106	1.03	21.8	-11.8	-7.50	33.9	-13.3	-7.04	4.02	3.31	-1.86	-5.75	0.025	-0.750	-0.821	47.6	-0.063
N x K	6.11	-0.99	1.84	-0.79	0.038	-0.106	-1.73	6.78	-10.2	-28.25	-26.6	-34.8	-1.13	-5.63	1.08	-19.8	-0.042	3.395	-0.250	4.79	-14.1	-3.31
N x L	4.08	3.73	1.97	2.71	-0.125	0.106	-0.463	6.92	-0.384	-1.00	75.3	2.13	-10.2	10.6	-6.54	34.3	15.0	5.23	-0.375	6.64	-32.6	-6.19
P x K	0.68	-0.99	-1.48	-2.57	-0.225	0.218	-0.675	13.4	18.3	-1.63	39.0	13.6	-3.71	12.5	0.920	55.2	5.96	0.536	-1.375	4.61	-40.5	-2.69
P x L	-2.36	1.28	-1.38	-0.98	0.038	0.081	0.113	14.9	6.49	17.9	-56.4	-27.4	1.26	12.4	-5.10	31.2	0.958	-0.750	0.250	-5.57	11.0	-0.31
K x L	1.96	-0.12	0.37	1.51	-0.088	-0.081	0.588	-21.5	-5.31	-13.1	-43.9	-51.2	-2.79	-3.82	-0.690	7.05	-1.00	-2.27	1.50	-7.93	1.25	-1.56
SE Linear Terms	104	101	56.1	32.9	2.06	2.11	44.5	406	280	43.8	388	507	220	79.5	55.7	327	31.9	67.0	8.7	107	147	18.5
SE Quadratic Terms	57.2	45.9	34.9	30.5	1.35	1.37	23.5	186	174	60.3	426	333	95.6	189	39.5	528	46.4	35.7	5.2	59.8	110	23.2
SE Interactive Terms	42.8	42.3	25.8	22.6	1.62	1.22	18.0	292	188	55.2	307	315	100	124	51.1	335	44.5	35.0	4.9	34.0	96	25.0
CV %	23.9	18.6	25.5	20.5	48.7	39.8	21.8	56.9	76.5	18.9	40.6	36.2	22.6	18.0	17.6	41.5	20.5	24.1	23.4	15.2	4.3	5.5
R ² %	23	19	20	15	8.2	14.0	22	7.3	11	53	39	35	17	15	7.1	17	16	15	65	33	64	45

Table 3.3. Experiment 3B: Constants and Coefficients of Response Surfaces for Responses

*** $\rightarrow P < 0.001$, ** $\rightarrow 0.001 \leq P < 0.010$, * $\rightarrow 0.010 \leq P < 0.050$ \rightarrow

to N, P, and K Fertilisation and Liming

0.050 $\leq P \leq 0.100$

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	Plant day 81	Width day 177	Foliage day 69	Height day 177	Leaf colour	Chlorophyll per area	Chlorophyll per fresh weight	Number of leaves	Dry weight foliage	Fresh weight/dry weight ratio	Leaf area per plant	Area per leaf	Number of leaves	Corn day 164	Diameter day 266	Corn growth per day	Corn thickness	Corn fresh weight	Maximum root length	Flower size	Foliar % N	Foliar % P	Foliar % K	Foliar % Ca	Foliar % Mg	Soil pH at harvest	Corn dry weight	
Constant	289	311	136	446	3.88	169	456	30.7	623.1	829.1	562.2	237.3	32.7	389	525	805	294.7	41.7	129	186	314	1229	1169	696	5940	1007	593	1682
N	25.1	26.7	12.3	49.4	0.381	13.7	49.4	3.11	92.4	-76.1	43.8	12.6	11.1	-11.4	3.55	93.4	4.13	1.38	-8.43	-2.30	0.042	171	34.8	-107	0.50	-16.2	-1.54	-33.6
P	-8.55	0.541	0.994	-0.027	0.131	-1.35	-0.028	2.29	23.9	-9.95	14.9	4.63	8.60	2.57	3.20	17.2	2.53	0.53	-0.992	-0.875	0.006	26.5	70.9	-50.8	431	24.4	-5.04	-2.38
K	-3.70	-1.18	-2.26	-4.833	-0.024	2.49	-4.83	1.52	12.0	15.1	10.9	3.46	-9.31	-1.92	0.454	38.2	-4.90	0.41	1.71	0.800	-0.077	81.6	13.8	199	123	-58.1	0.208	-83.2
L	3.93	6.08	2.74	15.611	-0.036	5.15	15.6	0.327	14.1	6.70	8.17	-0.125	-8.80	14.7	12.2	-24.3	4.49	2.41	-0.758	-5.10	0.042	-59.4	-13.9	94.9	343	42.9	31.2	22.3
N ²	-4.59	13.5	-2.08	-6.27	-0.179	-4.50	-6.27	-2.403	-35.3	45.1	-31.7	-2.11	-5.20	-4.96	-10.5	-16.7	-7.13	-2.01	0.442	0.562	-0.067	18.5	61.9	-23.8	-196	38.1	-1.43	-183
P ²	0.876	0.531	-1.56	16.6	-0.00	-1.32	16.56	-0.635	-13.0	19.9	-2.79	-2.79	-4.36	2.32	-0.736	-19.3	-3.69	-0.39	2.05	1.64	-0.174	1.5	17.2	58.7	115	-26.3	1.32	4.85
K ²	-2.55	2.77	0.74	0.146	-0.214	0.503	0.146	-0.528	-22.1	17.0	4.14	-2.74	2.29	1.15	-4.28	-50.2	-4.36	-0.440	-1.55	-0.038	-0.138	37.7	24.4	-29.1	45.4	29.3	2.57	-11.2
L ²	3.23	0.067	1.47	11.31	0.036	-0.205	11.3	0.650	7.74	11.6	4.74	6.14	2.49	3.70	7.37	1.83	6.10	2.37	-2.35	-3.14	0.004	-2.64	-19.1	14.7	-62.6	0.177	-13.43	-61.3
N x P	-3.49	2.19	-3.56	-9.79	0.018	-3.69	9.79	1.13	20.7	0.144	21.1	1.19	12.7	7.46	6.38	-55.0	4.64	0.827	-3.30	8.29	0.009	71.8	89.1	9.25	-15.0	-34.4	1.56	11.4
N x K	1.08	-2.42	3.33	-1.42	-0.143	-2.35	1.42	1.08	24.3	-28.8	11.4	2.56	-10.8	1.46	-2.89	-27.9	4.25	1.02	2.58	-4.10	0.027	144	-20.4	-58.6	419.8	20.9	-0.937	-63.4
N x L	-3.97	2.92	-0.116	8.25	0.161	-0.813	8.25	0.402	9.54	-3.36	14.7	0.813	-11.1	-0.781	-1.41	2.78	2.15	0.455	9.75	2.63	-0.045	94.1	-59.3	-121	-132	3.06	4.94	99.7
P x K	-5.96	-8.47	-2.88	6.42	0.054	0.979	6.42	1.19	10.8	21.4	5.25	-4.44	-11.4	1.56	3.18	-30.0	4.15	1.97	0.538	5.89	0.188	17.7	-42.6	-11.9	-259	-16.9	-2.94	94.0
P x L	-7.33	-3.24	-4.12	-1.83	0.142	1.77	-1.83	-0.455	10.2	14.0	12.8	6.06	-11.8	-0.556	3.02	59.2	3.13	-0.068	-2.16	1.44	0.080	-135	-17.4	-33.0	-252	-58.2	-3.69	62.8
K x L	-10.4	-1.21	-7.54	7.21	-0.054	3.10	7.21	0.098	-6.34	-13.2	-11.9	4.19	12.6	-4.13	3.26	31.5	-5.76	-1.70	0.963	0.775	-0.045	-9.06	5.06	85.6	-194	-46.9	-6.44	13.1
SE Linear Terms	176	178	83.5	176	2.63	63.2	221	27	753	608	373	34	147	147	102	364	63.7	21.2	67.3	44.3	0.631	490	199	613	1019	191	77.5	599
SE Quadratic Terms	58.3	69.8	37.3	58.3	1.52	18.6	71.0	13.5	269	300	219	18.7	117	50.3	87	212	72.6	20.7	47.8	49.3	1.19	300	191	243	872	146	26.8	1000
SE Interactive Terms	57.0	41.0	35.5	57.0	1.06	29.7	86.2	15.2	241	325	311	28.4	150	83.6	115	237	51.9	20.8	32.3	55.4	1.02	292	118	180	882	127	17.8	665
CV %	19.9	13.7	26.4	19.9	29.4	18.1	18.6	53.6	42.2	36.0	58.2	12.1	39.6	21.5	22.3	32.9	18.1	50.5	25.2	30.4	35.9	22.9	9.6	25.2	16.3	-13.0	3.0	44.9
R ² %	26	43	19	26	24	25	33	13	26	13	66	44	6.2	9.6	5.6	30	15	8.8	21	65	9.7	63	74	83	60	63	88	16

RESULTS

3.9 Nitrogen influenced many aspects of foliage growth, corm development and flowering (Figs. 3.1, 2, 3, 4, Plate 1). Additions of P, K, and L had a much less dramatic influence on cyclamen growth and flowering than N but were more prominent in Experiment 3B than 3A.

3.10 Foliage Growth

Foliage growth and quality responded strongly to N in both experiments (Figs. 3.1, 3.2, 3.3). In Experiment 3A the dimensions of the plant (foliage width, height, petiole length; Fig. 3.2, Plate 1) and leaf area (Fig. 3.1) were depressed above 450 g N m^{-3} but in Experiment 3B dimensions (Fig. 3.3) showed a positive response to 1200 g N m^{-3} . This result suggests interaction between N and other nutrients. Foliage width (Fig. 3.13) showed evidence of synergistic response to N and K but these two nutrients were antagonistic in their influence on leaf size (Fig. 3.17). In both experiments foliage colour showed a positive response to N (Figs. 3.1, 3.3) but fresh and dry weights were depressed by more than 600 g N m^{-3} .

The influence of P on foliage was subject to interaction with K. In Experiment 3A foliage colour was influenced by P and K (Fig. 3.11) but in Experiment 3B foliage colour responded to K independently of P (Fig. 3.9) showing best colour at 332 g K m^{-3} . In Experiment 3B plants were more compact in response where P and K (Fig. 3.25), and K and L (Figs. 3.23, 3.24) were at adequate balanced levels, a possible $P \times K \times L$ interaction. Foliage fresh weight was depressed by 12 kg m^{-3} Lime (Fig. 3.6).

3.11 Flowering

Flowering was strongly influenced by N in Experiment 3B. Flowering was earliest in Experiment 3A at high N (Plate 1) or P (Plate 2) levels but was delayed where both were high (Fig. 3.10). Addition of either N or P promoted early flowering independently in Experiment 3B (Figs. 3.4, 3.5). Number of flowers per plant was increased by N addition up to a maximum between 600 - 900 g N m⁻³ (Fig. 3.4). Flower quality was subject to interactions N x P, N x L, P x K, P x L, and K x L. Flower size was greatest where 400 g P m⁻³ and 332 g K m⁻³ were present (Fig. 3.26). The height of flowers in Experiment 3B was subject to N x L, P x L, and K x L interactions (Figs. 3.16, 3.21, 3.22) but flower stalk length in Experiment 3A responded only to N x P (Fig. 3.12). A synergistic N x L interaction influenced the dry weight of each flower (Figs. 3.15).

3.12 Corm and Root Growth

Corm diameter was depressed by N in the early stages of both Experiments (Figs. 3.2, 3.4) but this response disappeared at later stages when, in Experiment 3A, corm thickness was slightly depressed by 300 g N m⁻³ (Fig. 3.2). Phosphorus, K, and L, all showed some influence on corm growth. In Experiment 3B corm diameter was depressed by P and K fertilisation (Figs. 3.5, 3.9) but increased by Liming in Experiment 3A (Fig. 3.8). In Experiment 3B corm fresh weight was depressed by high levels of P or K but less so when both were high (Fig. 3.8).

Excessive root elongation occurred at low N and L levels but root growth was depressed where either of these nutrients was high (Fig. 3.14)

3.13 Foliar N, P, K, Ca, and Mg Levels

Foliar N content increased in a linear response to applied N. Foliar levels were highest when high levels of N and P were applied (Fig. 3.19). Foliar K levels were affected by applied K (Fig. 3.9) but was greatest at high applied L levels in the absence of N (Fig. 3.20). Foliar Ca responded slightly to P addition (Fig. 3.5) and foliar Mg was depressed by K addition (Fig. 3.9). Soil pH was, as might have been expected, increased by Liming (Fig. 3.8).

3.14 Discussion

The maximum levels of nutrients supplied in Experiment 3A did not generally cause strong depression of growth and flowering, nor were any other symptoms of toxicity present. The second experiment was carried out to investigate the influence of very high levels of fertilisation. Far from depressing growth or causing salinity problems, the high rates served to dramatically increase response to N and the number of significant responses to other nutrients. The shape of many of the curves was altered from a slightly convex quadratic form to straight lines, a change which has been observed before where levels of more than one nutrient are changed (Bould, 1972). The largest plants in Experiment 3B were 1/3 wider and taller with more and larger flowers than those in Experiment 3A. *Cyclamen persicum* will survive in media of unusually high nutrient and lime content and even when the term spent in the same pot is considered

will respond to much higher levels than the 720 g N m^{-3} commercially applied (Thomas, 1979; personal communication) when 8½ month osmocote is used.

Good responses to N have been recorded for most pot plants (e.g. Thomas, 1979; Khoo, 1979; Lai, 1979; Teoh, 1979) including *C. persicum* (Miura, 1968, 1970). The work reported here and in particular Experiment 3B, indicates that cyclamen have a higher N requirement than has been suggested by Bunt (1976) and that this species can respond to up to $150 \text{ g N m}^{-3} \text{ month}^{-1}$. This is higher than the requirement reported by Thomas and Spurway (1974) for rapidly growing plants. Miura (1968, 1970) reported suppression of cyclamen root growth by N, but in Experiment 3A this was true only below 6 kg L m^{-3} and at 12 kg L m^{-3} root growth was enhanced by N addition (Fig. 3.14).

In both experiments flowering was earlier with greater N. It is usual for flowering to be earlier with ammonium than with nitrate as N source (although this is no rigid rule, Haynes, Goh, 1978). Because most plants respond differently to each N source (Haynes, Goh, 1978) it is likely that cyclamen do also. There is no evidence to show which N source was responsible for earlier flowering or indeed whether both sources were responsible.

Phosphorus was important to flower quality and precocity of flowering (Figs. 3.10, 3.5, 3.26, 3.21, 3.22, 3.12) but usually in interaction with other nutrients. Experiment 3B (Fig. 3.5) confirms the results of Gugenhan (1969b) who found that flowering of cyclamen is delayed by P shortage but in Experiment 3A flowering was delayed by P addition when N was high (600 g N m^{-3} , Fig. 3.10). Schwemmer (1975)

postulated an interaction between P and K influencing flower quality and number. In Experiment 3B, P and K showed synergistic influence on flower size (Fig. 3.26) but there was no evidence in either experiment of an effect on flower number. Miura (1968) reported that P had little influence on cyclamen shoot or root growth. The results here confirm this report.

Most plants have a wide luxury range in response to K in which the balance with other nutrients becomes more important than concentration (Bunt, 1976; Boodley, 1969). It was no surprise therefore that K was involved in a number of interactions. There is a strong relationship between K and nitrate uptake, but K competes with ammonium uptake (Green, 1967a). The antagonism between N and K on leaf size (Fig. 3.17) in Experiment 3B and their synergistic influence on plant width in Experiment 3A (Fig. 3.13) cannot be fully understood until it is known how each N-source is involved. Miura (1968) reported that K addition increased cyclamen leaf size. Figure 3.17 shows this trend to be reversed when high levels of N are present. The same article reports an increase in fresh weight with K but most results have shown little influence of K on vegetative growth of cyclamen (Freisdorf, Verschenstalt, 1973; Augé, Vidalie, 1977; Schwemmer, 1975). In the experiments reported here with the exception of foliage colour (Fig. 3.9), foliage responded to K only in interaction with other nutrients (Figs. 3.11, 13, 17, 25). From other work (Freisdorf, Verschenstalt, 1973; Augé, Vidalie, 1977) it was expected that K would show strong influence on flower number and quality. Flower stalk length responded to K (Fig. 3.7) in Experiment 3A but in Experiment 3B flower height was

depressed by K above 18 kg L m^{-3} (Fig. 3.22). This interaction may be a result of the strong influence L had on foliar K levels (Fig. 3.20), a relationship which may be due to the necessity of Ca to membrane permeability (Haynes, Goh, 1976) and K uptake mechanism but restricted by competition occurring between anions for uptake sites (Boodley, 1969; Klougert, Olsen, 1969; Hannan, Holley, Goldsberg, 1978).

Corm diameter and thickness were depressed by K addition, but corm fresh weight was depressed less by K addition if P was also increased (Fig. 3.18). In contrast with Miura (1968), K was not found to improve root growth.

These results agree with other authors (Mantova *et al.* 1970; Schwemmer, 1975; Miura, 1968, 1970) that cyclamen will respond to high levels of K fertilisation.

Miura (1968, 1970) reported that excessive lime suppressed growth and caused leatheryness of cyclamen leaves. Hangitae (1976) reported that although cyclamen prefer low pH conditions, they have a high requirement for Ca. The results reported here however, suggest a high tolerance to lime where no attempt has been made to increase medium buffering capacity and thus reduce the influence of lime on pH (Figs. 3.15, 3.16, 3.14). Lime did depress foliage and flower growth when P or K levels were also high (Figs. 3.21, 3.23, 3.24). Increased foliage fresh weight at high lime levels (Fig. 3.5) which was not related to an increase in dry weight suggests an increase in succulence which may have been what Miura described as leatheryness.

Lesant

Lesant and Brunet (1976) found a lower pH optimum for growth of *C. persicum* in the second month than for the first. This suggests a continuously changing optimum, information on which cannot be derived from this work.

Experiment 3B indicates a response to extraordinarily high soil nutrient levels and tolerance of levels much higher than the usually recommended maximum. These results should therefore be interpreted with some caution and more experimentation is needed to confirm that the same result will be arrived at in different conditions. Both experiments were carried out in the warmer half of the year under high natural illumination. In conditions less conducive to rapid growth, it is possible that the levels applied successfully in Experiment 3B would prove highly phytotoxic.

CHAPTER FOUR

THE INFLUENCE OF SEVERAL GROWTH-REGULATING CHEMICALS ON GROWTH AND FLOWERING OF CYCLAMEN PERSICUM

4.1 Abstract

In four experiments the influence of gibberellin treatment, its timing, number of treatments, and interaction with B-nine Cycocel, and Phosphon-D was examined. GA_3 gave small decreases in time to flower but was ineffective if treatment was late. Retardants counteracted flowering advancement without correcting other side effects of GA_3 .

4.2 Introduction

It has been stated by Jansen (1960) that the time of gibberellin treatments is important to their influence on flowering of *C. Persicum*. Comparisons between reports (see Chapter One) show, however, that a wide range of timings have given success. Recommendations for technique and number of applications also vary. One or several applications separated by between 12 hours and two months have been recommended (Jansen, 1960; Kohl, Kofranek, 1957; Widmer *et al.*, 1979; Widmer *et al.*, 1974; Neuray, 1971a, Augé, Vidalie, 1977). Gibberellin treatments may result in side effects which detract from flower quality. Some attempt has been made by Neuray (1971) to counteract these side effects by use of GA in combination with growth retardants.

Three experiments are described below to reassess the value of Gibberellic acid (GA_3) for advancing flowering of cyclamen (Experiment 4B) to investigate the importance of number of treatments (Experiment 4C) and timing (Experiments 4A, 4C) and to assess interactions between GA_3 and growth retardants (Experiments 4A, 4B, 4C, and 4D).

MATERIALS AND METHODS

4.3 Experiment 4A: The Influence of Late Gibberellin Treatment on Flowering of *C. persicum*.

Mixed varieties of 12 month old cyclamen within 30 days of flowering were arranged into randomised block design of five treatments and 20 replicates. A 20 ml aqueous solution or suspension containing 5 ppm EtoH 25 ppm surfactant and the treatments shown in Table 4.3 was sprayed to the crown of each plant. The plants remained in a heated automatically ventilated glasshouse and were watered by hand.

Flowering was assessed for six weeks after treatment being counted as they appeared noting unusually elongated stipes or distorted flowers. Maximum height of the flowers was measured from the top of the corm.

Results were compared using Duncan's new multiple range test.

4.4 Experiment 4B

Five month old *C. persicum* 'Bonfire' plants approximately 10 cm in diameter were used in an experiment of identical design and treatments to 4A but with 15 replicates. Plants were growing in a medium as prescribed for treatment "O, O, O, O" of Experiment 3A under similar

environmental and pest control conditions. Assessment of flowering continued for nine months. As cyclamen tend to flower unevenly, as many as 10% of flowers may require 35 days longer than average to flower (Widmer, 1976) an arbitrary "good saleable" standard was set at which six flowers had been produced by each plant. Not all plants reached this standard, which cannot therefore be compared directly with the average number of days to flowering. Plant width was measured as in Experiment 3A at completion of the trial.

Results were compared using Duncan's new multiple range test.

An experiment (4C) using similar treatment applied at various stages of plant growth was unsuccessful as a result of disease problems (see Appendix 2).

4.5 Experiment 4D: Interactions between GA_3 , B-nine, Cycocel and Phosphon-D treatments of *C. persicum*.

The experimental design was identical to that used in nutrition trials 3A and 3B (Section 3.3) with the nutrients replaced by growth regulators in a logarithmic range of quantities as shown in Table 4.2. Treatments were sprayed to the crown as described in Experiment 4A (Section 4.3). GA_3 treatments were applied on 20th June, 1978, and B-nine, Cycocel, and Phosphon-D on the 21st, 22nd, and 23rd June, respectively. Plants were grown in media prescribed for treatment (1, 1, 1, 1) of Experiment 3A (Table 3.1) but conditions were otherwise as described for Experiment 3B.

Assessments were similar to those made in Experiments 3A and 3B except that as these plants were not destructively harvested leaves were measured from a randomly selected 20 leaves per treatment. Data was analysed as described for Experiment 3A.

Table 4.1 Treatments Applied in Experiment 4C

Level Name	GA ₃ µg Plant ⁻¹	N-nine Mg Plant ⁻¹	Cycocel Mg Plant ⁻¹	Phosphon µg Plant ⁻¹
-2	0	0	0	0
-1	20	10	6	0.2
0	200	50	60	20
1	2000	250	600	2000
2	20,000	1250	6000	200,000

These figures have been rounded off for convenience, the quantities actually used can be calculated from the following:

$$\begin{array}{|c|c|c|c|} \hline 2 \times 10^{n-2} & 2 \times 5^{n-2} & 0.6 \times 10^{n-0.6} & 0.002 \times 10^{2n} \\ \hline & & & -0.002 \end{array}$$

where $n = 0, 1, 2, 3, 4$, for

level = -2, -1, 0, 1, 2, respectively.

Table 4.2. Experiment 4A: Influence of Late GA₃ Treatment on Flowering of *C. persicum*

Treatments	Number of Flowers		Flower Height (mm)	Number of Plants Showing	
	4 Weeks	8 Weeks		Excessive Elongation*	Incomplete Reflexion*
Control (distilled water)	5.9 a	21.2 a	157 a	0	5
200 µg GA ₃ plant ⁻¹	4.2 a	17.0 a	173 ab	3	9
500 µg GA ₃ plant ⁻¹	5.2 a	19.6 a	187 b	3	7
1000 µg GA ₃ plant ⁻¹	3.5 a	16.4 a	172 ab	0	3
50 mg B-nine plant ⁻¹	4.4 a	17.0 a	169 a	4	1
CV %	78.5	56.7	14.8		

Means not followed by the same letter were different at the 5% level by Duncan's new multiple range test.

* This data not statistically analysed.

Table 4.5. Experiment 4C: Constants and Co-efficients of Response Surfaces for Responses to

*** \rightarrow $P < 0.001$ ** \rightarrow $0.001 \leq P < 0.010$ * \rightarrow $0.010 \leq P < 0.050$ # \rightarrow GA_3 , B-nine, Cycocel, and Phosphon-D $0.050 \leq P \leq 0.100$

	Flower size	Stipe diameter	Flower height	Days to flowering	Days to six flowers	Total number of flowers	Foliage width	Foliage height	Area per leaf	Dry weight per leaf	Foliage colour	Petiole thickness	Lamina thickness	Petiole length	day 96 Corm	Diameter day 243
Constant	2.87	2.83	20.5	192	208	19.7	26.25	13.58	349	356	3.02	2.83	3.33	3.33	501	727
GA_3	0.192*	-0.133	0.042	-0.921	0.083	-0.508	0.525	0.096	-34.42**	-39.3*	-0.079	-0.45*	-0.125	0.083	2.52	8.26
B-nine (B-9)	-0.100*	-0.025	0.208	-2.15	-3.00	1.26	-0.500	0.304	-1.50	-1.21	0.004	0.041	-0.417	0.00	-0.963	-0.004
Cycocel (CCC)	-0.223	-0.158	-1.46	-0.179	-0.333	-0.325	-2.225	0.129	1.33	3.37	0.121	-0.208	0.125	-0.083	-25.1***	-48.6***
Phosphon-D	0.042	0.042	0.292	-2.30	-0.750	0.325	-0.350	0.196	16.88	26.7	0.054	0.292	0.042	0.250	-5.95	-10.4
$(GA_3)^2$	0.154	-0.025	0.594	-0.21	-0.438	0.871	0.582	-0.120	-2.42	-6.34	0.036	-0.052	0.135	0.104	-4.60	1.95
(B-nine) ²	0.192	0.087	0.469	0.49	2.94	-0.604	0.117	0.092	8.83	7.16	-0.026	0.197	0.135	-0.021	2.28	8.35
(Cycocel) ²	-0.296***	-0.300***	-2.031*	4.27	-0.433	-0.741	-2.22***	-0.095	-12.42	-11.7	0.086	-0.177	0.010	0.104	-11.9	-64.4***
(Phosphon-D) ²	0.117	0.113	0.344	1.49	2.188	0.821	-0.108	-0.132	12.58	18.7	0.049	0.323	0.135	0.146	-7.45	-1.65
$GA_3 \times B\text{-nine}$	0.125	0.050	-0.063	-2.49	-1.13	-1.26	-0.500	0.106	4.88	-7.56	0.131	-0.063	0.063	0.00	-8.19	-0.76
$GA_3 \times \text{Cycocel}$	-0.088	-0.088	0.188	-5.71	-3.50	-1.90	0.175	0.131	-19.6	71.3	-0.031	-0.063	-0.188	0.00	3.74	-2.01
$GA_3 \times \text{Phosphon-D}$	-0.013	-0.050	0.188	-1.32	-2.50	-0.938	-0.025	-0.081	6.13	-11.93	-0.018	0.188	-0.063	0.00	1.48	-5.81
B-9 \times Cycocel	-0.013	0.038	0.063	2.53	2.50	-0.875	-0.513	-0.119	-1.75	1.06	0.056	-0.063	0.188	0.250	-8.81	-3.78
B-9 \times Phosphon-D	-0.188*	-0.125	0.063	-3.08	-3.50	0.188	-0.563	-0.206	0.500	3.96	0.119	-0.063	0.063	0.250	7.61	-15.4
CCC \times Phosphon-D	0.000	0.138	-0.688	-3.47	0.875	-1.08	0.388	-0.206	15.5	-14.1	0.031	-0.313	0.313	0.00	1.86	-16.3
SE Linear Terms	2.48	1.65	3.67	25.5	7.62	12.6	18.3	3.07	29.7	117	1.20	1.43	0.46	0.68	201	390
SE Quadratic Terms	2.28	2.07	4.02	41.7	10.0	14.2	13.3	1.88	15.3	51.9	0.95	0.88	0.64	0.88	95.4	366
SE Interactive Terms	1.30	1.30	3.95	44.9	10.3	14.5	10.8	2.65	5.2	84.7	1.12	0.69	0.90	1.19	105	193
CV %	44.6	47.5	19.7	22.7	4.9	72.9	71	19.8	14.7	23.4	35.8	22.6	24.5	35.4	21.7	28.3
R ² %	23	18	52	6.2	47	7.8	15	6.5	62	47	72	72	32	22	13	26

Table 4.3. Experiment 4B: Influence of GA₃ and B-nine on Flowering of *C. persicum*

Treatments	Days to Flowering	Number of Flowers	Plant Width	Days to Six Flowers
Control	220 a	12.0 a	202 a	235 a
200 µg GA ₃ plant ⁻¹	202 a	11.6 a	203 a	223 b
500 µg GA ₃ plant ⁻¹	209 a	13.9 a	219 a	215 c
1000 µg GA ₃ plant ⁻¹	195 a	13.1 a	206 a	198 d
50 mg B-nine plant ⁻¹	207 a	12.1 a	189 a	228 ab
CV %	23.2	66.6	15.9	4.6

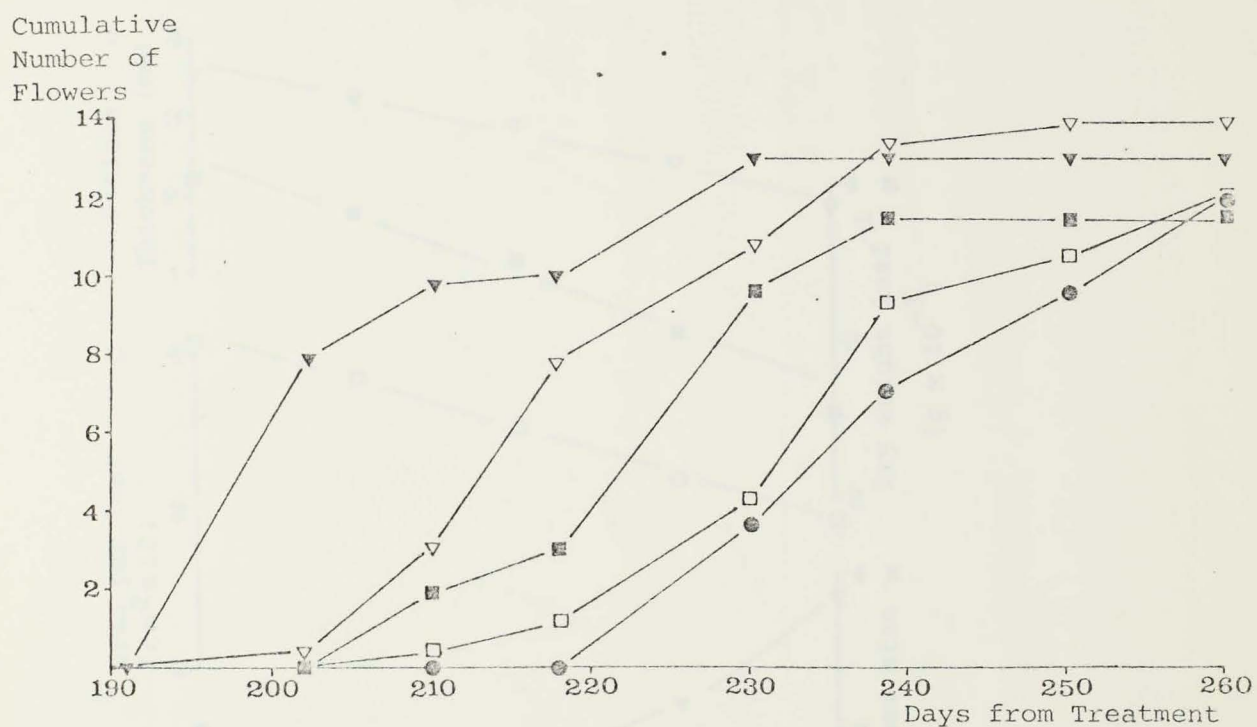
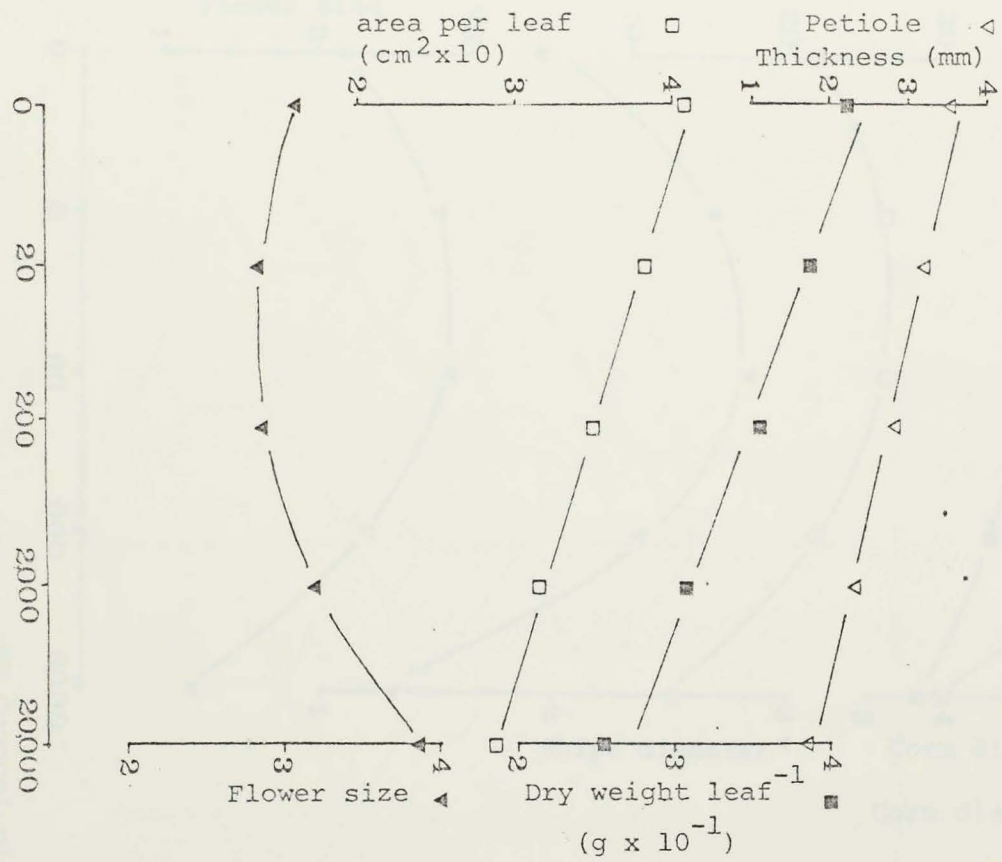


Fig. 4.1. Experiment 4B: Number of Flowers Produced Per Plant Against Time

- Control
- B-nine 50 mg plant⁻¹
- GA₃ 200 µg plant⁻¹
- ▽ GA₃ 500 µg plant⁻¹
- ▼ GA₃ 1000 µg plant

No statistical analysis was carried out of this data in the form presented here.

Fig. 4.2 Experiment 4b: Influence of GA_3



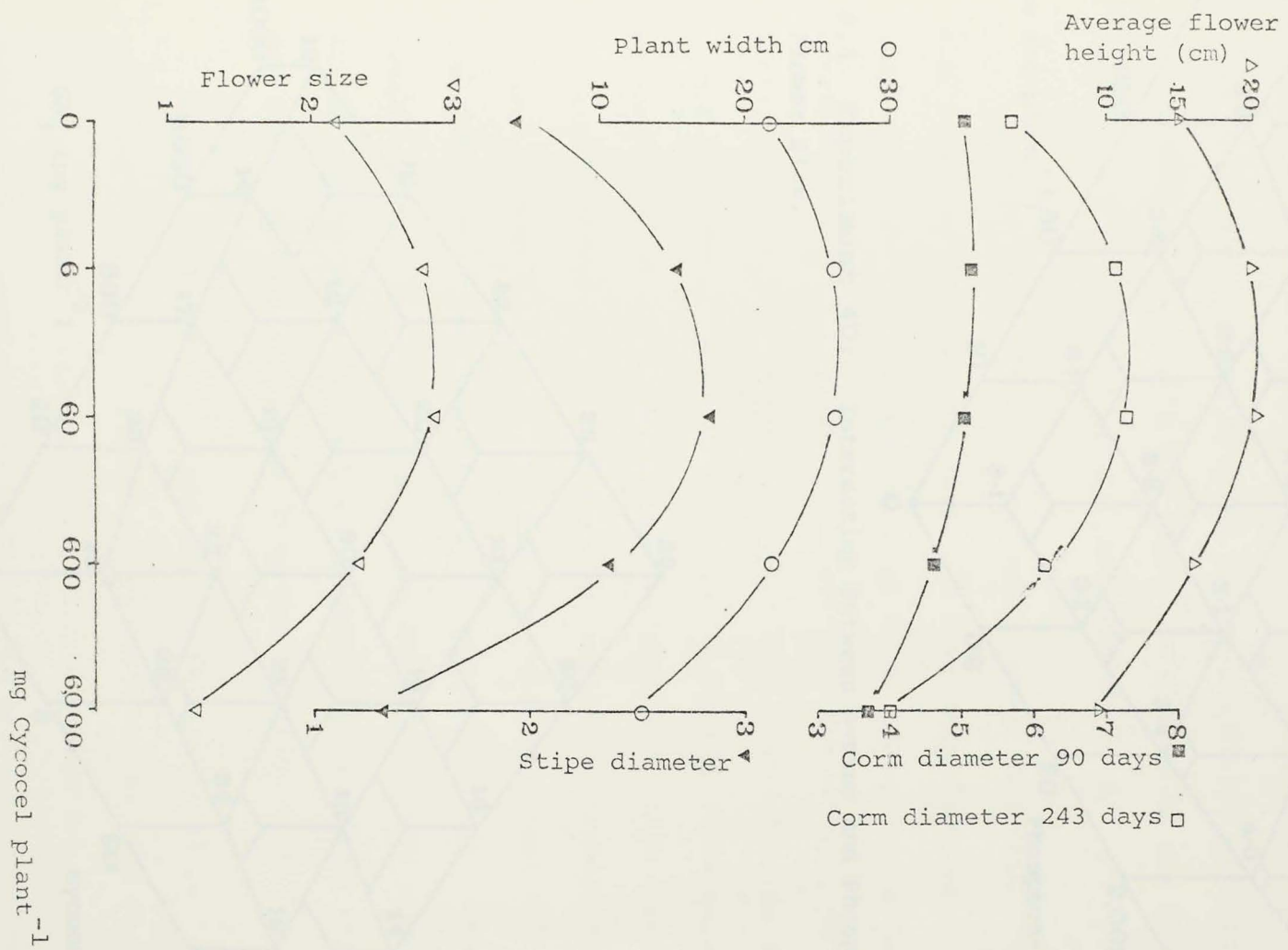


Fig. 4.3. Experiment 4D: Responses to Cycocel

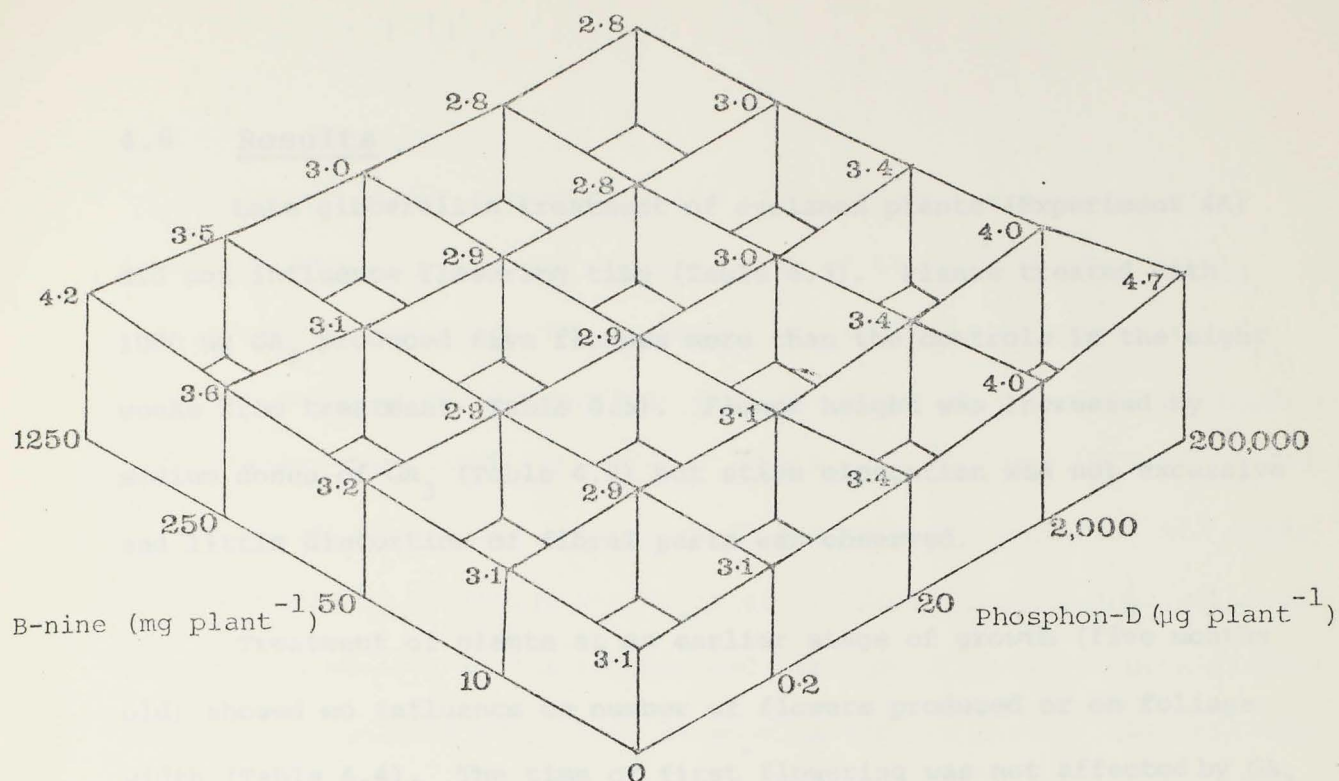


Fig. 4.4 Experiment 4D: Interaction Between B-nine and Phosphon-D on Flower Size.

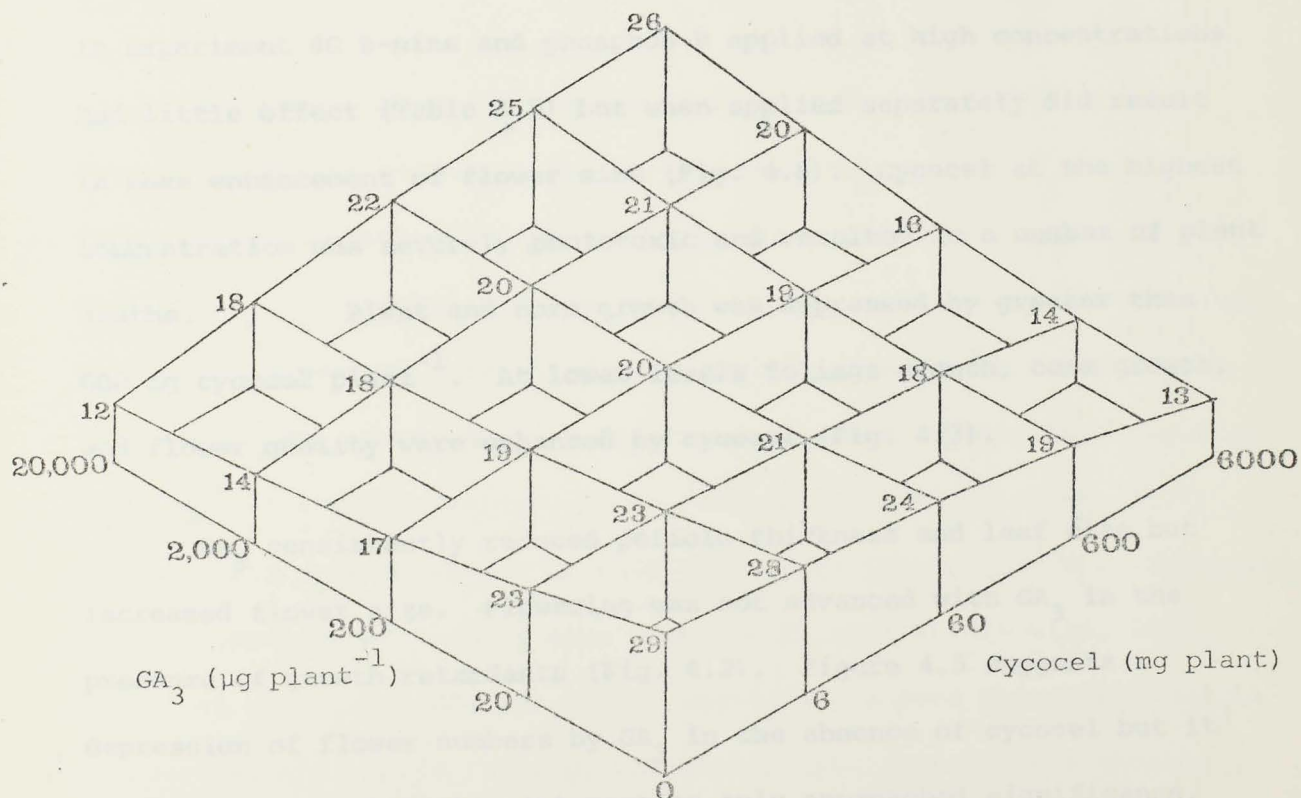


Fig. 4.5 Experiment 4D: Interaction Between GA₃ and Cycocel on Total Number of Flowers.

4.6 Results

Late gibberellin treatment of cyclamen plants (Experiment 4A) did not influence flowering time (Table 4.3). Plants treated with 1000 $\mu\text{g GA}_3$ produced five flowers more than the controls in the eight weeks from treatment (Table 4.3). Flower height was increased by medium doses of GA_3 (Table 4.3) but stipe elongation was not excessive and little distortion of floral parts was observed.

Treatment of plants at an earlier stage of growth (five months old) showed no influence on number of flowers produced or on foliage width (Table 4.4). The time of first flowering was not affected by GA_3 treatment but treated plants subsequently produced their flowers more rapidly (Fig. 4.1), six flowers having been produced up to 35 days sooner by plants treated with 1000 $\mu\text{g GA}_3$ than by control plants. In Experiment 4C B-nine and phosphon-D applied at high concentrations had little effect (Table 4.5) but when applied separately did result in some enhancement of flower size (Fig. 4.8). Cycocel at the highest concentration was severely phototoxic and resulted in a number of plant deaths. Plant and corm growth was depressed by greater than 600 mg cycocel plant^{-1} . At lower levels foliage growth, corm growth, and flower quality were enhanced by cycocel (Fig. 4.3).

GA_3 consistently reduced petiole thickness and leaf size but increased flower size. Flowering was not advanced with GA_3 in the presence of growth retardants (Fig. 4.2). Figure 4.5 suggests a depression of flower numbers by GA_3 in the absence of cycocel but it should be noted that this interaction only approached significance.

4.7 Discussion

Jansen (1960) stated that the effectiveness of gibberellin treatment depended upon the concentration of GA and the stage of bud development at which the treatment was applied. A comparison of Experiments 4A and 4B confirms that the stage of treatment was important, but a further experiment (Appendix 2) failed to contribute further information on the effect of timing and number of treatments. Widmer *et al.* (1974) reported that no advantage was to be gained from repeated applications, and the variability in the recommended timings of sprays between different authors suggests that there is some margin for error. The influence of GA₃ is on development rather than initiation of flowers (Neuray, 1971a). Therefore treatment must be after formation of flowers and at least 60 days before required flowering (i.e. somewhat longer before natural flowering).

Experiment 4D confirmed the finding of Neuray (1971a) that Cycocel or B-nine destroyed the advantage of GA₃ treatment but did not show any enhancement of stipe growth by these retardants alone, as did Neuray. In the experiments reported here, GA₃ conferred little advantage on initial flowering date but flower production was more rapid beyond this time. The advancement of flowering time has usually been reported as under three weeks (Parups, 1979; Jeff, 1977; Augé, Vidalie, 1977) and may with some cultivars be only a few days (Parups, 1979). The more rapid production of flowers also reported by Augé and Vidalie, 1977, Widmer *et al.*, 1974, Neuray, 1971a, means that a more saleable plant is produced slightly more rapidly, but that plants flower for a shorter period than untreated plants.

PRACTICAL IMPLICATIONS

5.1 Germination

The germination experiments did not succeed in demonstrating a consistent means of gaining optimum cyclamen germination. Gibberellin treatments did increase speed of germination but associated decreases in germination percentages make this treatment unacceptable. Soaking seed in still or flowing water for 48 hours prior to sowing will improve germination speed without decreasing germination percentage.

Drenches of 10 ppm terrazole to the seed medium and/or seed dip in 1 g l^{-1} Benlate (benomyl 50% a.i.) is recommended as a precaution against pathogenesis.

5.2 Nutrition

Cyclamen will tolerate relatively high levels of fertilisers in soil-less media, but most efficient use of fertilisers is likely to occur where these are supplied in several small doses or as a slow release fertiliser rather than one (for P, K, L) application as in the experiments described in Chapter Three. Osmocote (8½ month 18/2.6/10) is recommended for cyclamen, a plant which will spend at least six months in the final pot. The required nitrogen can be supplied from 5.1 kg m^{-3} of this fertiliser but supplying all N from this source will give higher than recommended K levels. N levels can be made up with 3.3 kg m^{-3} osmocote (18/2.6/10) and by 420 g m^{-3} IBDU (31% N), the latter being split into two applications. The P level is made up with 8 kg m^{-3} 9% super-phosphate. An alternative is 4.4 kg fine Magamp with 1.9 kg IBDU and 0.28 kg potassium sulphate. To cover the full period the magamp should be

supplied in two dressings as it releases over 5 - 6 months. With either regime 9 kg of Dolomite lime and 3 kg agricultural lime should also be supplied.

These are larger doses of fertilisers than are usually recommended for potted plants. Their use therefore should occur only after careful retesting of these results and of their applicability in the conditions in which they are to be used. In these experiments these nutrient levels did result in good growth and flowering of cyclamen in a peat/sand medium. In making these practical recommendations the influence on corm growth was regarded as unimportant. Where cyclamen are grown for cut flowers, slightly lower P and K levels may produce larger flowers (Fig. 3.26).

FLOWERING

Sprays of up to 50 ppm GA_3 to the crown of cyclamen plants has been reported to advance flowering by up to three weeks (Chapter One) but the time advantage is usually much smaller. This treatment can result in excessive elongation of flower stipes and flower distortion. These malformations have not been successfully counteracted by other chemicals.

Response varies with variety, growth stage, chemical used, application rate and technique of treatment. It is therefore recommended that each user empirically calibrate his own concentration to allow for his techniques, conditions and spray equipment. A careful look should be taken at the value of a slight advancement in flowering date of a plant which will normally take from 9 - 12 months under present

New Zealand cultural conditions.

Advances in flowering can be gained through environmental (Neuray, 1973; Widmer *et al.* 1979; Maatsch, 1971; Andersen, 1966; Asma, 1973; Maatsch, Kaeffer, 1957) and nutritional (see Chapter Three) adjustments in conjunction with the use of early flowering F_1 hybrid plants. Gibberellin treatments should be considered as part of an integrated control of flowering.

ACKNOWLEDGEMENTS

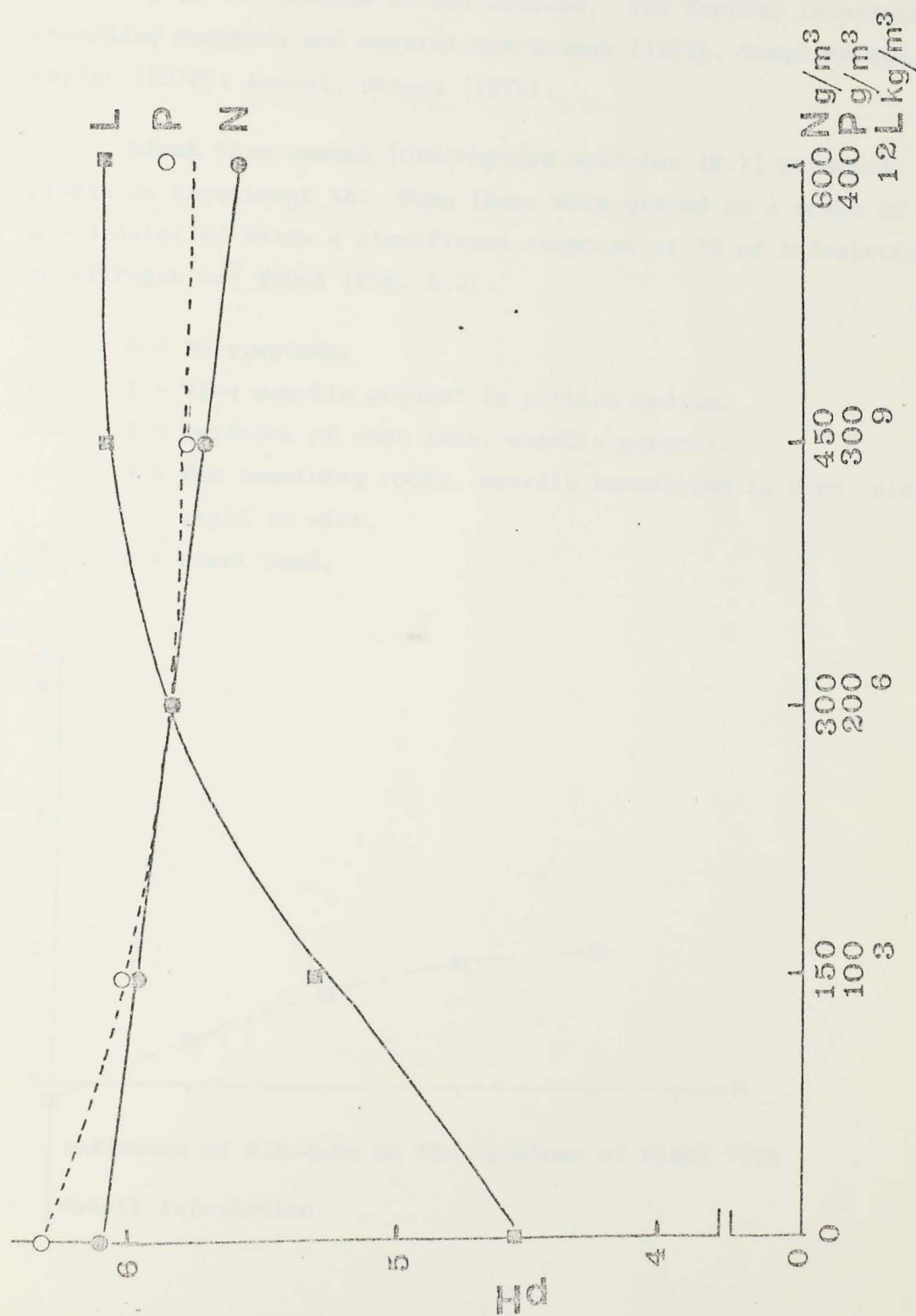
My thanks to my supervisor, Mike Thomas, for making his help available when necessary without excessive interference. Particular thanks go to Mike for his (repeated) proof-reading of this article.

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APPENDIX 1

Fig. A.1. The Influence of N, P, and L on pH of Peat/Sand Media.



APPENDIX 2

Fusarium oxysporum f. sp. *cyclaminis* or vascular wilt of cyclamen was discovered causing disease and high mortality in the experiment described in Appendix 3. This was diagnosed by M.A.F. plant diagnostic centre at Lincoln and believed to be the first discovery of the disease in New Zealand. For further information regarding symptoms and control see Grouet (1973), Tompkins and Snyder (1972); Rouxel, Grouet (1975).

Black vine weevil [*Otiorhynchus sulcatus* (F.)] attacked plants in Experiment 3A. When these were graded on a scale of 0 - 4 detailed below a significant response of 70 of infestation to Nitrogen was found (Fig. A.2).

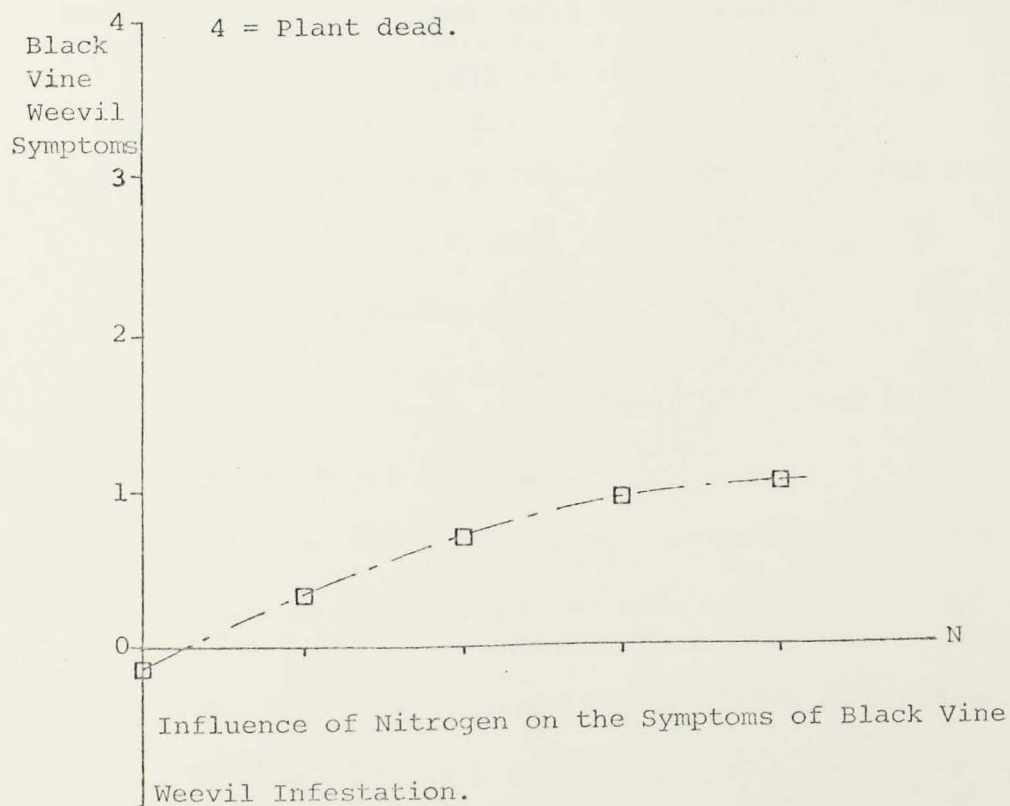
0 = No symptoms.

1 = Vine weevils present in potting medium.

2 = Evidence of root loss, weevils present.

3 = Few remaining roots, weevils tunnelling in corm, plant rapid to wilt.

4 = Plant dead.



APPENDIX 3

A further experiment was carried out for inclusion in Chapter Four. The aim was to further investigate the influence of treatment timings, and of multiple treatments. Under the conditions described for Experiment 4B, an experiment was carried out applying the treatments described in that Experiment to plants at three months, five months, or on both occasions. This trial was so decimated by *Fusarium oxysporum* f. sp. cyclaminis that no significant differences occurred.

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